Desalination and Water Treatment
www.deswater.com

doi: 10.5004/dwt.2022.28325

255 (2022) 94–100
April

Diagnosis and improvement of diffuser performance of Fouka Desalination Plant (Algeria)

M. Amitouche[a], A. Lefkir[b,*], B. Remini[c], M.S. Sebki[d], L. Aissaoui[d]

[a]Boumerdes University, Boumerdes 35000 Algeria, email: m.amitouche@univ-boumerdes.dz
[b]Laboratory of TPiTE, ENSTP, Algeria, email: a_lefkir06@yahoo.fr/a.lefkir@enstp.edu.dz (A. Lefkir)
[c]Blida University, Algeria
[d]ENP, Laboratory of Construction and Environment, Algeria

Received 28 July 2021; Accepted 14 February 2022

ABSTRACT

A significant increase in salinity, which sometimes exceeds 40 g/L, has been observed in the intake waters of Fouka station located in Tipaza State (Algeria). An interaction was suspected between the discharge and the intake waters due to insufficient dilution or a deviation of the brine plume. The purpose of this study is to diagnose this diffuser and to investigate its behaviour concerning climatic variations such as wind velocity and current velocity. To achieve this, we simulated several dispersion scenarios of release in the marine environment using the Cornell Mixing Expert System (CORMIX) code. Indeed, the environmental speeds related to both wind and current play an important role in the development of the plume and therefore the dilution of the brine. To further exploit the simulation results, we plotted the plume profiles in space for the three velocity cases (favourable, intermediate, and unfavourable) according to UTM (Universal Transverse Mercator) coordinates, considering the position of the water intake point. Alternatives and solutions were proposed at the end of this analysis, to improve the performance of this diffuser.

Keywords: Desalination; Brine; Interaction; Environmental impact; Diffuser; CORMIX

1. Introduction

Seawater desalination is considered being an unconventional drinking water supply technique, and an alternative that seems relevant and inevitable given the current global water shortage [1,2]. The number of desalination plants continues to grow worldwide and more particularly in the Mediterranean region [3–5]. Indeed, several stations have been installed and all discharge significant quantities of effluent (brine) into the Mediterranean Sea [4,5].

Besides being two to three times more loaded with salt than the Mediterranean basin [4], these discharges also comprise various heavy metals and chemicals, which in the long term could prove harmful to the marine ecosystem [6,4]. This effluent is discharged into the sea to be diluted using special diffusers and the dilution depends on the configuration of the latter. Optimal sizing of a brine diffuser is therefore essential to ensure the acceptable dilution of the discharge and minimize its impact on marine life [7].

Brine is discharged from underwater outfalls as a turbulent jet, with an initial density significantly higher than the density of the ambient water (seawater) [8].

The first work on desalination discharges was published by Holly et al. [9] on the model of discharge systems in two parts: the laboratory study of the discharge system in the first part, and dispersion tests in some estuary models in the second part [10]. Zeitoun and McIlhenny [11] completed the experimental work of Holly et al. [10] in a third part with a numerical simulation and design considerations of desalination plant discharge systems.

---

[*] Corresponding author.

Presented at the International Virtual Conference on Water and Energy (ICWE 21), Hassiba Benbouali University of Chlef, Algeria, 25–27 May 2021

Chaung and Goldschmidt [12] developed turbulent diffusion in liquid jets. Curtet and Hopfinger [13] presented a theoretical synthesis on the calculations of neutral and buoyant jets. Kotsovinos and List [14], Kotsovinos [15] developed in two parts the properties of flat buoyant turbulent jets. Downie [16] had analysed numerically in his thesis the flow of a turbulent free jet. Lee [17] developed an analytical model of a vertical turbulent jet. Papanicolaou [18] made a theoretical and experimental analysis of mass and momentum transport in an asymmetric vertical turbulent buoyant jet. Gosman and Simitovic [19] studied the mixing of a confined jet in the laboratory. Wilson [20] went further in modelling jets of varying composition in generalized crossflows. Roberts [21] carried out a transport and dilution prediction study of oceanic discharges.

Doneker [22] and Doneker and Jirka [23] developed an expert system (CORMIX1) for the analysis of the mixing zone of discharges through a single discharge port. Akar et al. [24] developed the work of Doneker [22] and Doneker and Jirka [23] to establish another expert code for the analysis of discharge from a multi-port diffuser (CORMIX2). Chen [25] in his research work presented theoretical detail and experimental results on turbulent jets and plumes in a flowing environment. Gowda [26] conducted field and laboratory research on mixing tubes in marine discharge systems. Jirka et al. [27] provided a hydrodynamic model of surface discharge mixing (CORMIX3).

The CORMIX computer code adapted to model brine waste discharges that can predict dispersion, mixing and plume trajectory is widely used in the field and cited and tested by several authors [7,8,28–36].

In this present work, we will first study the current hyper-saline discharge diffuser of the Fouka Desalination Plant as well as its behaviour concerning climatic variations through multiple simulations using a specialized "CORMIX" model to diagnose this diffuser for three possible scenarios of environmental velocity couples (favourable, intermediate, and unfavourable).

2. Materials and methods

2.1. Simulation parameters

The Fouka station located in the Wilayah of Tipaza has a production capacity of 120,000 m^3/d and a brine discharge flow of about 153,000 m^3/d, the latter is discharged directly into the marine environment at a depth of 7 m, by an underwater outfall with a length of 370 m, equipped with a single-port diffuser of 2.8 m and a diameter of 1.1 m (Fig. 1).

A set of parameters common to all scenarios, representing the data and characteristics of the Fouka seawater desalination plant, has been established to allow comparison and discussion (Table 1).

Location of the intake point: XUTM = 478,161 m; YUTM = 4,060,090 m; the intake is at 5.0 m from the seabed and its alignment is shown in Fig. 1.

Location of the discharge of the brine: XUTM = 478,374 m; YUTM = 4,059,604 m; the depth is 7 m, the waste is taken at 2 m from the seabed at 45° from the horizontal and in a northeast direction. The alignment of the outfall is shown in Fig. 2.

2.2. CORMIX model

For larger rivers, lakes, and the marine environment, modelling using the CORMIX (Cornell Mixing Expert System) software is widely used, particularly in studies and practical applications in the field of marine discharges and mainly brine discharges from desalination plants. In the present work, the software has been used under a License (License ID N°75183932). CORMIX is a 3D simulation code of turbulent buoyant jet mixing behavior which covers a majority of common discharge and environmental conditions (Fig. 3).

Fig. 1. Photo of the brine discharge diffuser of Fouka station.

Table 1
Characteristics of the Fouka Desalination Plant

Effluent characteristics		Diffuser characteristics	
Maximum discharge rate	1.77 m^3/s	Distance from the coast	370 m
Salinity	69 g/L	Depth at pour point	7 m
Salinity increase	31.5	Length of diffuser section	2.8 m
Density (19.5°C)	1,050.586 kg/m^3	Number of ports	1
Characteristics of the environment		Diffuser height	2 m
Salinity	36.5 g/L	Port diameter	1.1 m
Density (19.5°C)	1,025.801 kg/m^3	Flow output speed	1.86 m/s
Wind speed	2–8 m/s	Discharge angle	45°
Current speed	0.02–0.4 m/s		

The hydrodynamic simulation system contains a collection of regional flow models based upon integral, length scale, and passive diffusion approaches to simulate the hydrodynamics of near-field and far-field mixing zones.

Efficient computational algorithms provide simulation results in seconds for mixing zone problems with space scales of meters to kilometers and time scales of seconds to hours.

Dilution in turbulent buoyant jets is caused by entrainment of surrounding ambient material into the discharge plume. In this region, the initial jet characteristics of momentum flux, buoyancy flux, and outfall geometry influence jet trajectory and mixing.

CORMIX contains a rigorous flow classification scheme developed to classify a given discharge/environment interaction and mixing behavior into one of several flow classes with distinct hydrodynamic features. The classification scheme places major emphasis on the near-field behavior of the discharge and uses the length scale concept as a measure of the influence of each potential mixing process. Flow behavior in the far-field, after boundary interactions, is largely controlled by ambient conditions. Once a flow has been classified, integral, length scale, and passive diffusion simulation modeling methods are utilized to predict the flow process details.

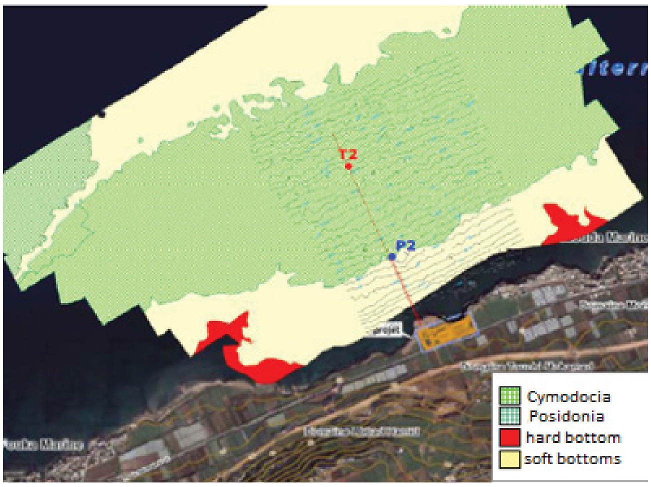

Fig. 2. Bathymetry, with the P2 intake, and T2 discharge points [37].

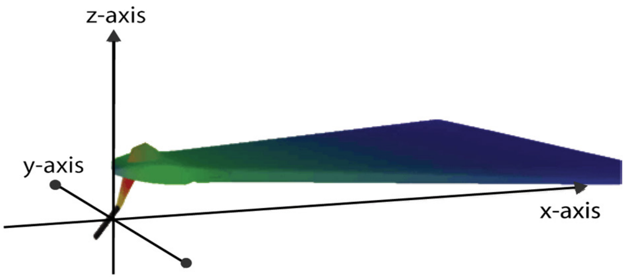

Fig. 3. CORMIX simulation of plume dispersion in 3D-single port discharge (Doneker and Jirka [42]).

The classification scheme is implemented within CORMIX using artificial intelligence (AI) techniques of rule-based expert systems.

These techniques are used to assist in technology transfer and to give the analyst flexible and powerful tools for mixing zone analysis.

Integral models use hydrodynamic equations governing the conservation of mass and momentum, and of other quantities as pollutant mass, density deficit, temperature and/or salinity, are solved stepwise along the general curved jet trajectory.

The solution yields values of the trajectory position itself and of the centerline concentrations of these quantities, while the actual cross-sectional distribution is fixed a priori (mostly as a Gaussian distribution) in these models.

For near-field mixing of stable discharges, CORMIX uses the CorJet model that solves the three-dimensional jet integral equations for submerged buoyant jets – either a single round jet or interaction multiple jets in a multiport diffuser – in a highly arbitrary ambient environment. The ambient/discharge conditions include an arbitrary discharge direction, positive, neutral or negative discharge buoyancy, an arbitrary stable density distribution, and a non-uniform ambient velocity distribution with magnitude and direction as a function of vertical position (Fig. 4) (Doneker and Jirka [42]).

A series of simulation parameters common to all the scenarios have been established to allow comparison in similar situations. These are the parameters relating to seawater, brine, and outfall discharge. The use of this software requires prior information on the hydrodynamics prevailing in the field of study to know the longitudinal evolution of the effluent plume in time and space.

3. Results and discussions

The required effluent dilution rate has been calculated and corresponds to *S* = 34.5. In other words, the salinity of the discharge, which is equal to 69 g/L, must be diluted a little more than 30 times so that the plume generated does not exceed the tolerated concentration of 38.5 g/L when mixed with seawater.

S: dilution.

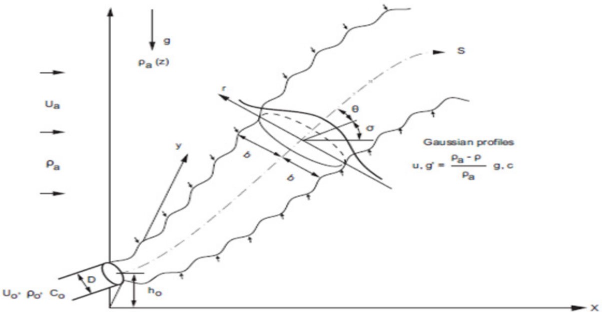

Fig. 4. General three-dimensional trajectory of submerged buoyant round jet in stratified cross flow (Doneker and Jirka [42]).

Table 2
Cases of environmental speeds studied

Type of case	Current velocity (m/s)	Wind velocity (m/s)
Case1: Favourable	0.4	8
Case2: Intermediate	0.2	6
Case3: Unfavourable	0.02	2

3.1. Diagnosis of diffuser behaviour in the receiving environment

To diagnose the behavior of the diffuser, we performed simulations for three scenarios of velocity pairs (favorable, intermediate, and unfavorable) Table 2.

Fig. 5 shows the different dilutions for the three-speed pairs (current, wind) mentioned above. Concerning the first and third cases, the required dilution rate will never be reached, that is, the brine discharged will always have a salinity that exceeds the permissible limit for the receiving environment, which is very bad for the marine ecosystem.

As for the second case, the dilution rate is reached after having travelled 140 m, that is, well after the end of the near field ($X = 54.37$ m). The results also showed us that the plume hits the ground directly after it leaves the discharge source, which is very bad for the seabed.

Based on these results, we can say that the current diffuser of the Fouka Desalination Plant is not in conformity, because under all possible conditions, it does not offer a good dilution of the brine, thus the negative impact on the environment will be high. For this reason, modifications or even alternatives of the diffuser must be made.

To exploit the results of the simulations, we have plotted for the three cases mentioned above, the plume profiles in space according to UTM (Universal Transverse Mercator) coordinates considering the position of the water intake point, the results are presented in Figs. 6–8.

In the case of unfavourable environmental speed conditions (case 3), with wind direction parallel to the discharge speed (SIGMA = 0°), clearly notices in Fig. 5, a translation of the plume by the sea current in the direction from the water intake.

To see the effect of the direction of the current on the dispersion of the brine in the marine environment, Fig. 6, shows the simulation results in case (case 3), with a horizontal angle SIGMA = 90°.

With low wind speed and current (case 3) and a direction perpendicular to the discharge speed (SIGMA = 90°), Fig. 9 shows a significant translation of the plume in the direction of the water intake point (plume is approaching the water intake point), which increases the risk of interaction between the discharge water (brine) and the collection water in the event of high wind speed and SIGMA angle direction greater than 90°.

X, Y and Z: three-dimensional Cartesian coordinates, the position of a point is given by the x, y and z distances.

XUTM and YUTM: The X and Y coordinate projection in the Universal Transverse Mercator or UTM system is a type of conformal map projection of the Earth's surface.

Horizontal Angle σ (SIGMA): the angle measured counter-clockwise from the ambient current direction to the plane projection of the port center line (defines the direction of the current).

3.2. Improvements and alternatives to the current diffuser

In this section, we will see the dilution results for several port diameters (discharge velocities), which is a very important factor for the dilution of the brine. We will also see the effect of variation in the number of ports (installation of a multi-port diffuser) on the dilution of the brine [7].

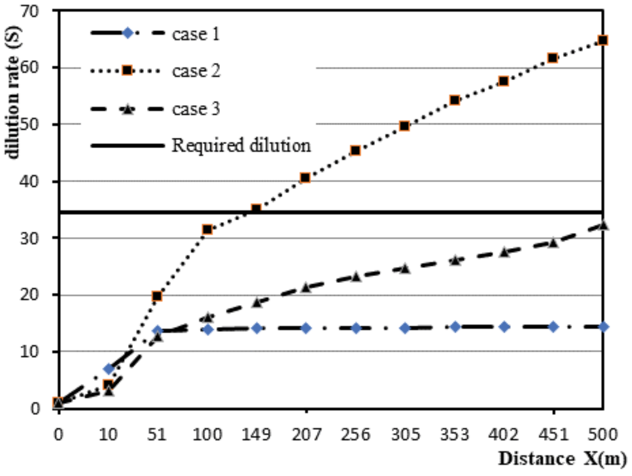

Fig. 5. Graphs of dilutions as a function of different environmental velocities.

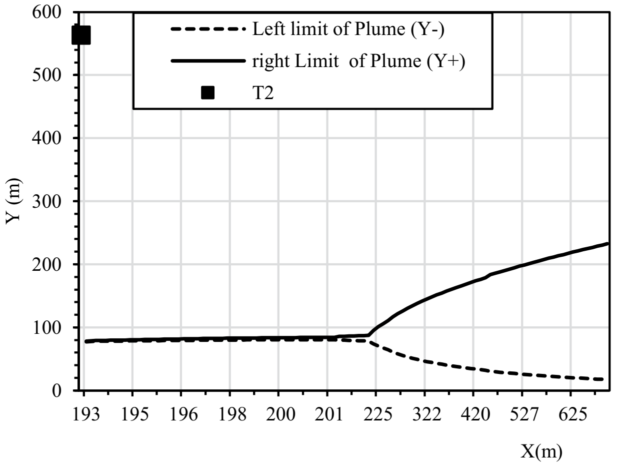

Fig. 6. Lateral profile of the plume (Y function X) in space for the favorable case (Case 1).

3.2.1. Variation in port diameter (rejection rate)

For a discharge angle of 45°, a diffuser height of 2 m at a depth of 7 m and an environmental current velocity of 0.4 m/s. Fig. 7 shows the different dilutions for the 5 different diameters *D* = 0.5 m (9 m/s), *D* = 0.8 m (3.52 m/s), *D* = 1.1 m (1.86 m/s), *D* = 1.5 m (1 m/s) and *D* = 2 m (0.56 m/s).

We observe that the best dilution condition is given by higher diffuser outlet velocities and consequently by lower diameters. In other words, the higher the exit velocity, the better the dilution.

We observe that for the diameters 1.1, 1.5, and 2 m the required dilution rate is not reached, therefore these three diameters are to be excluded, among them, the 1.1 m diameter corresponding to the diameter of the current diffuser of the Fouka station (Fig. 10).

Concerning the diameters 0.5 m and 0.8 m, the two configurations give us a good dilution of the brine and the required dilution rate is reached in the near field for both diameters. However, for the 0.5 m diameter, the required dilution rate is reached after 47.5 m from the discharge point. For the 0.8 diameters, the required dilution rate is reached at 83.4 m from the discharge point.

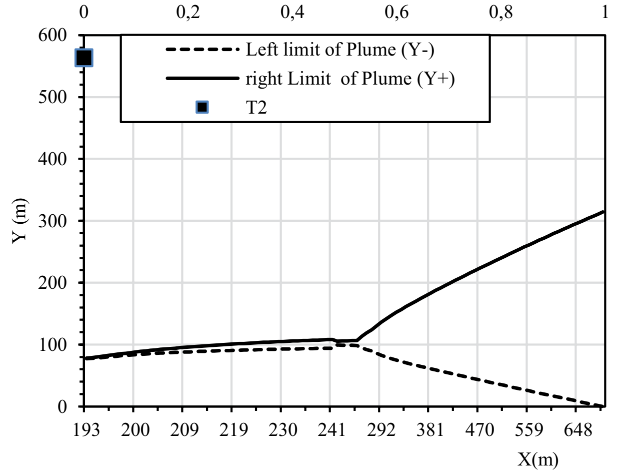

Fig. 7. Lateral profile of the plume (Y function X) in the space for the intermediate case (Case 2).

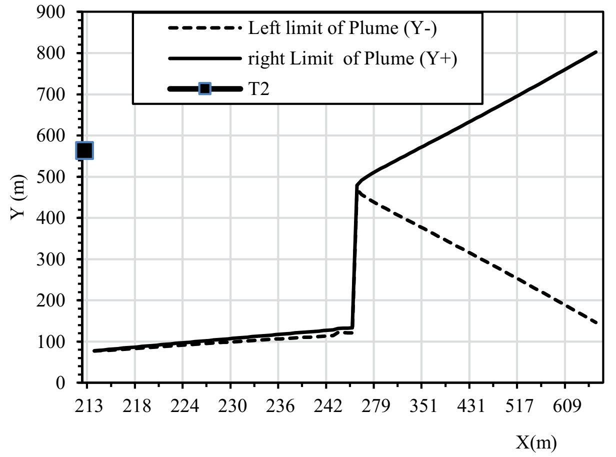

Fig. 8. Lateral profile of the plume (Y function X) in space for the unfavourable case (Case 3).

Therefore, both diameters 0.5 and 0.8 m are recommended with a slight advantage for the 0.5 m diameter.

3.2.2. Variation in the number of ports

To ensure a good dilution of the brine rejected by the desalination plant of Fouka, by improving the performances of the current single-port diffuser, the installation of a multiport diffuser could be an appropriate solution [23]. For this reason, we have varied the number of ports while accompanying this with a change of diameter, to keep the same rejection speed.

We considered the following data, shown in the table (Table 3):

Fig. 11 shows the different dilutions for each type of diffuser. We notice that in our case, the more the discharge ports are numerous, the better the dispersion of the brine and therefore the better the dilution of the brine. Important simulation results are presented in Table 4.

According to these results, for the 3-port diffuser configuration, the required dilution ratio is not achieved. This configuration is therefore excluded. The other three diffuser configurations are acceptable. The dilution ratio is achieved before the end of the near field and before the plume touches the sea bottom. However, the first 30-port configuration remains in the lead because the dilution ratio is reached at

Table 3
Proposed alternatives of diffusers

Type of diffuser	Length (m)	Ports diameters	Number of ports
1	100	0.2	30
2	50	0.29	15
3	25	0.39	8
4	10	0.65	3

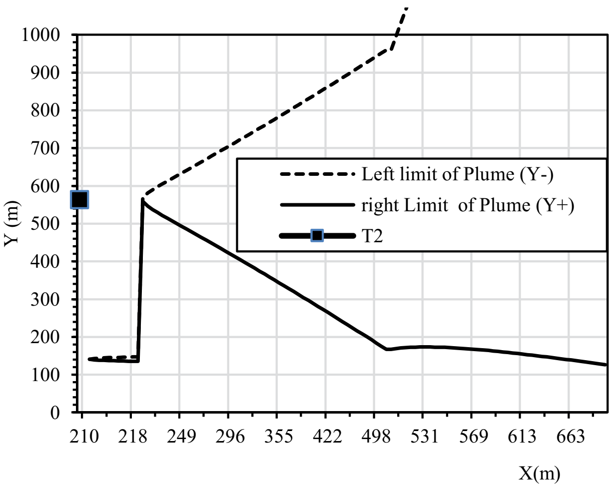

Fig. 9. Lateral profile of the plume (Y as a function of X) in space for the unfavourable case (Case 3) and SIGMA = 90.

Table 4
Simulation results

Type of diffuser	Distance travelled to reach the required dilution (m)	Distance travelled before the plume encroaches on the bottom (m)	Near field length (m)
1	2.5	50	50
2	4.5	25	25
3	8.75	12.5	12.5
4	>500	5	5

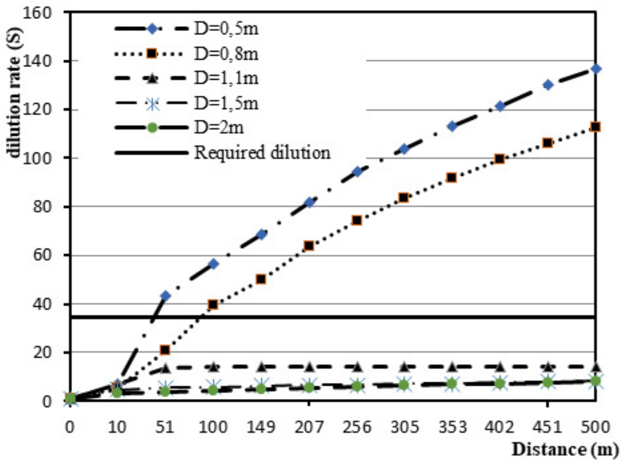

Fig. 10. Graphs of dilutions as a function of different port diameters.

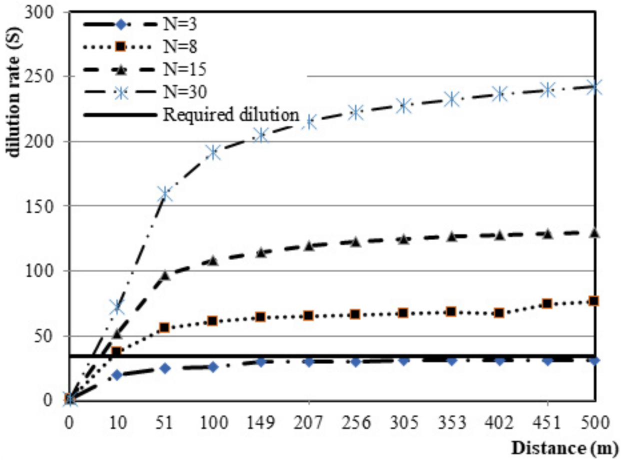

Fig. 11. Graphs of the dilutions according to the different types of diffusers (number of ports N).

the closest distance from the discharge point. The choice of one of these three configurations is based on economic considerations.

4. Conclusion

After a diagnosis of the current installation of the diffuser of the Fouka Desalination Plant, the diffuser shows a failure in these performances. On the other hand, great interaction between the catchment water and the brine discharge was observed for the case of low environmental velocities (unfavourable case), by tracing the lateral profile of the plume and the water intake point.

To propose solutions for improving the performance of the diffuser, simulations were proposed by increasing the discharge velocity on the one hand, and by increasing the number of discharge points, on the other hand, to ensure good dilution and avoid, consequently, a negative impact on the marine ecosystem.

Furthermore, it would be very interesting, in perspective, to install a dilution system upstream of the discharge outfall, at the level of the coast or the desalination plant itself, to further minimize the impact of brine discharges on the marine environment [38–41].

References

[1] B.K. Pramanik, L. Shu, V. Jegatheesan, A review of the management and treatment of brine solutions. Environ. Sci. Water Res. Technol., 3 (2017) 625–658.

[2] A. Panagopoulos, K.-J. Haralambous, M. Loizidou, Desalination brine disposal methods and treatment technologies – a review, Sci. Total Environ., 693 (2019) 133545, doi: 10.1016/j.scitotenv.2019.07.351.

[3] H. Khordagui, Assessment of the Potential Cumulative Environmental Impacts of Desalination Plants Around the Mediterranean Sea, Project Funded by the European Union, Final Report Activity 1.3.2.1, 2017.

[4] PNUE/PAM, Lignes directrices techniques et évaluations connexes Lignes directrices actualisées relatives à la gestion des activités de dessalement, UNEP(DEPI)/MED WG.439/7, Athens, 2017.

[5] E. Jones, M. Qadir, M.T.H. van Vliet, V. Smakhtin, S.-m. Kang, The state of desalination and brine production: a global outlook, Sci. Total Environ., 657 (2019) 1343–1356.

[6] S. Lattemann, Development of an Environmental Impact Assessment and Decision Support System for Seawater Desalination Plants, Doctoral Thesis, DOCTOR, Delft, The Netherlands, 2010.

[7] M. Amitouche, Impacts des rejets des stations de dessalement sur le milieu récepteur, Doctoral Thesis, Biskra University, Algeria, 2016.

[8] A. Niepelt, Development of Interfaces for the Coupling of Hydrodynamic Models for Brine Discharges from Desalination Plants, Diploma Thesis, University of Karlsruhe, Institute for Hydromechanics, 2007.

[9] F.M. Holly, J.L. Grace, Model Studies of Outfall Systems for Desalination Plants (Part I-Flume Study), Research Report N°714, United States Department of the Interior, 1971.

[10] F.M. Holly, J.L. Grace, Model Studies of Outfall Systems for Desalination Plants (Part II-Tests of Effluent Dispersion in Selected Estuary Models), Research Report H-71-2, U.S. Army Waterways Experiment Station, Vicksburg, Mississippi, 1971.

[11] M.A. Zeitoun, W.F. McIlhenny, Model Studies of Outfall Systems for Desalination Plants. Part III. Numerical Simulation and

Design Considerations, Research and Development Progress Report N°804, 1972.

[12] S.C. Chaung, V.W. Goldschmidt, Turbulent Diffusion in Liquid Jets: Final Report, U.S. Environmental Protection Agency, Washington, D.C., 1974.

[13] R. Curtet, E.-J. Hopfinger, Calculs et expériences sur les jets neutres et flottants, La Houille Blanche, 60 (1974) 551–573.

[14] N.E. Kotsovinos, E.J. List, Plane turbulent buoyant jets. Part 1. Integral properties, J. Fluid Mech., 81 (1977) 25–44.

[15] N. Kotsovinos, Plane turbulent buoyant jets. Part 2. Turbulence structure, J. Fluid Mech., 81 (1977) 48–62.

[16] M. Downie, The Numerical Analysis of Turbulent Free Jet Flows, Thesis, Sheffield Hallam University Research Archive, United Kingdom, 1978.

[17] D.W. Lee, An Analytical Model for a Vertical Buoyant Jet, Master, OAK Ridge National Laboratory, United States Department of Energy, 1980.

[18] P.N. Papanicolaou, Mass and Momentum Transport in a Turbulent Buoyant Vertical Axisymmetric Jet, Report No. KH-R-46, Laboratory of Hydraulics and Water Resources, California, 1984.

[19] A.D. Gosman, R. Simitovic, An experimental study of confined jet mixing, Chem. Eng. Sci., 41 (1986) 1853–1871.

[20] M. Wilson, Integral Modelling of Jets of Variable Composition in Generalised Crossflows, Ph.D. Thesis, University of Bath, 1986.

[21] P.J.W. Roberts, Dilution and transport predictions for ocean outfalls, Water Sci. Technol., 21 (1989) 969–979.

[22] R.L. Doneker, CORMIX1: An Expert System for Mixing Zone Analysis of Conventional and Toxic Single Port Aquatic Discharges, Thesis Presented to the Faculty of the Graduate School of Cornell University, 1988.

[23] R.L. Doneker, G.H. Jirka, Expert System for Hydrodynamic Mixing Zone Analysis of Conventional and Toxic Submerged Single Port Discharges (CORMIX1), Technical Report, United States Environmental Protection Agency, EPA, 1989.

[24] P.J. Akar, CORMIX2: An Expert System for Hydrodynamic Mixing Zone Analysis of Conventional and Toxic Multiport Diffuser Discharges, United States Environmental Protection Agency, EPA, 1991.

[25] H.B. Chen, Turbulent Buoyant Jets and Plumes in Flowing Ambient Environments, Ph.D. Thesis, Aalborg: Department of Civil Engineering, Aalborg University, Denmark, 1991.

[26] R.N. Gowda, Field and Laboratory Studies of Mixing Tubes for Marine Outfalls, Thesis, Faculty of Engineering and Applied Science, Memorial University of Newfoundland, Canada, 1992.

[27] G.H. Jirka, R.L. Doneker, S.W. Hinton, User's Manual for CORMIX: A Hydrodynamic Mixing Zone Model and Decision Support System for Pollutant Discharges into Surface Waters, DeFrees Hydraulics Laboratory School of Civil and Environmental Engineering, Cornell University, Ithaca, New York 14853–3501, 1996.

[28] T. Bleninger, Coupled 3D Hydrodynamic Models for Submarine Outfalls: Environmental Hydraulic Design and Control of Multiport Diffusers, Doctoral Thesis, Institute for Hydromechanics, University Karlsruhe, 2006.

[29] T. Bleninger, G.H. Jirka, Modelling and environmentally sound management of brine discharges from desalination plants, Desalination, 221 (2008) 585–597.

[30] A.S. Al-Ghamdi, Simulation of Jeddah multi-port sea outfall, J. Coastal Conserv., 14 (2010) 63–69.

[31] A. Purnama, H.H. Al-Barwani, T. Bleninger, R.L. Doneker, CORMIX simulations of brine discharges from Barka plants, Oman, Desal. Water Treat., 32 (2011) 329–338.

[32] Á. Loya-Fernández, L.M. Ferrero-Vicente, C. Marco-Méndez, E. Martínez-García, J. Zubcoff, J.L. Sánchez-Lizaso, Comparing four mixing zone models with brine discharge measurements from a reverse osmosis desalination plant in Spain, Desalination, 286 (2012) 217–224.

[33] S. Maalouf, D. Rosso, W.W.-G. Yeha, Optimal planning and design of seawater RO brine outfalls under environmental uncertainty, Desalination, 333 (2014) 134–145.

[34] T.M. Missimer, B. Jones, R.G. Maliva, Eds., Intakes and Outfalls for Seawater Reverse-Osmosis Desalination Facilities: Innovations and Environmental Impacts, Springer International Publishing, Switzerland, 2015.

[35] L. Balas, N. Yilmaz, Numerical modeling of near and far field dilution: Edremit sea outfall, Int. J. Adv. Mech. Civil Eng., 5 (2018) 41–54.

[36] J.A.R. Naranjo, A.G. Trujillo, Analysis of the Performance of Different Brine Diffuser Technologies with CFD Software, The International Desalination Association World Congress on Desalination and Water Reuse 2019/Dubai, UAE, 2019.

[37] SDEM, étude Environnementale de l'usine de dessalement d'eau de mer (SDEM) d'Alger ouest à Fouka, Algérie, Rapport interne, 2006.

[38] M. Amitouche, B. Remini, Operation of Cap Djinet desalination plant and dilution of brine with power station cooling water, Desal. Water Treat., 57 (2016) 3514–3521.

[39] Y. Fernández-Torquemada, J.L. Sánchez-Lizaso, J.M. González-Correa, Preliminary results of the monitoring of the brine discharge produced by the SWRO desalination plant of Alicante (SE Spain), Desalination, 182 (2005) 395–402.

[40] J.J. Malfeito, J. Díaz-Caneja, M. Fariñas, Y. Fernández-Torrequemada, J.M. González-Correa, A. Carratalá-Giménez, J.L. Sánchez-Lizaso, Brine discharge from the Javea desalination plant, Desalination, 185 (2005) 87–94.

[41] J.L. Sánchez-Lizaso, J. Romero, J. Ruiz, E. Gacia, J.L. Buceta, O. Invers, Y.F. Torquemada, J. Mas, A. Ruiz-Mateo, M. Manzanera, Salinity tolerance of the Mediterranean seagrass *Posidonia oceanica*: recommendations to minimize the impact of brine discharges from desalination plants, Desalination, 221 (2008) 602–607.

[42] R.L. Doneker, G.H. Jirka, CORMIX USER MANUAL A Hydrodynamic Mixing Zone Model and Decision Support System for Pollutant Discharges into Surface Waters EPA-823-K-07-001 December 2007 (Updated February 2017).