CONSEQUENCES OF BRINE DISCHARGES FROM SEAWATER DESALINATION ON THE MARINE ECOSYSTEM, CASE STUDY OF THE KAHRAMA STATION IN THE NORTH WEST OF ALGERIA

KASSOUAR, S.[1*] – ATTAB, K.[1] – DERGAL, N. B.[2*] – ABI-AYAD, S. E. A.[1]

[1]*Laboratory of Aquaculture and Bioremediation (AquaBior), Department of Biotechnology, University of Oran 1 – Ahmed Ben Bella, BP 1524 El M'Naouer, Oran 31000, Algeria*

[2]*Laboratory of Biotechnology for Food Security and Energetic, Department of Biotechnology, University of Oran 1– Ahmed Ben Bella, B.P 1524, El M'Naouer, Oran 31000, Algeria*

**Corresponding authors*
e-mail: sche_kass@yahoo.fr; dergalnadir@gmail.com

(Received 23rd Oct 2023; accepted 19th Jan 2024)

Abstract. This pioneering study, conducted for the first time in Algeria, investigates the negative impacts of brine discharges from the Kahrama seawater desalination plant in northern Algeria on marine flora and fauna. This research consisted of underwater observations at the brine discharge point (*in situ*). These observations revealed the existence of a layer of foam and debris on the surface of the water, most likely caused by the chemicals used in the washing water, such as antifoams, anti-scaling agents and other biocides. The seawater in the area appeared cloudy and contained suspended particles, which corresponded to the results of a comparison of the physicochemical parameters of the seawater before desalination and the discharged water. This comparative assessment revealed that the latter contained particularly high levels of calcium (2915.57 ± 482.27 mg/L) and total dissolved solids (46877.14 ± 635.84 mg/L). Banks of green algae closely resembling *Caulerpa prolifera* (Forssk.) were also noticed. In addition, the benthic vegetation had completely disappeared inside the landfill zone, leaving a stony environment invaded by sea urchins, indicators of pollution in this ecosystem.

Keywords: *Benthic flora, pollution, sea urchins, waste water, desalination plant*

Introduction

Since 2008, global desalination efforts have grown exponentially due to increasing demand for fresh water improving technologies and economic viability (Zapata-Sierra et al., 2021). Seawater desalination (SW) represents approximately 60% of desalination efforts globally and more than 80% around the Mediterranean (Elsaid et al., 2020). It is also the most energy-intensive type of desalination due to the high salt concentration in the feed water (Lior et al., 2017; Shah et al., 2022). We are also witnessing a very strong increase in the volume of water produced by desalination which was 45 million m^3/day in 2017 (Kara and Khaldi, 2017) and reached 95 million m^3/day in 2018 worldwide. Furthermore, hydrological changes caused or induced by climate change make it more difficult to sustainably manage water resources, which are already under severe pressure in many regions of the world (Papa et al., 2023). Around the Mediterranean, 76% of freshwater production is ensured by reverse osmosis installations. The largest plants are located in Spain, the main producer (31% of total capacity) with more than thirty desalination plants with medium to high capacity, between 20,000 and 125,000 m^3/day, followed by Algeria (20%), Israel (18%) and Libya (11%) (Pulido-Bosch et al., 2019).

DOI: http://dx.doi.org/10.15666/aeer/2202_12811295

Faced with these vital challenges and in order to remedy water stress especially in view of the scarcity of rain due to the harmful effects of global warming, Algeria has decided, and has been doing so for almost twenty years, to rely on desalination of seawater in order to replace natural resources in the majority of cities in northern Algeria (Bessenasse and Filali, 2014). Algeria, which has 1200 km of coastline, currently has 21 desalination stations spread across 14 coastal Wilayas (cities) and 7 others under construction, and 81 dams (with a total capacity of 9 billion m^3), which come under the Ministry of Water Resources (MWR, 2023). These desalination stations currently provide 17% of the water consumed in the country and supply 6 million people with a volume of 2.6 million m^3/day (MWR, 2023). The largest station is that of Mactaa, located in the Wilaya of Oran in the west of the country, with a capacity of 500,000 m^3/day of drinking water with a long-term objective of more than 2 million m^3/day. It is one of the largest reverse osmosis installations in the world (Kara and Khaldi, 2017). Most desalination stations use the reverse osmosis membrane technique, with the exception of the Kahrama station located in the Bethioua industrial zone in ARZEW, 40 km from the city of Oran. The Kahrama plant is Algeria’s pioneering seawater desalination complex, inaugurated in August 2005. It uses a Multi-Flash (MSF) distillation process using energy from electricity generation and produces 90,000 m3/day of drinking water (Gacem et al., 2012; Mokrani and Moudjari, 2022). Despite the advantages of seawater desalination for the production of fresh water, the latter nevertheless causes considerable damage to the marine environment.

The main impacts of seawater desalination on the marine environment are associated with two components: the intake of seawater towards the plant and the discharge of brine (Panagopoulos and Haralambous, 2020). Indeed, the main effects associated with the withdrawal of seawater are the entrainment and collision of marine organisms (Shokri and Sanavi Fard, 2023). Brine is the hypersaline discharge from a membrane plant and the hypersaline and hot discharge from a thermal desalination plant. Brine also includes various chemicals, antifoulants and antifoams used primarily as biocidal agents in the pre-treatment of water as well as the post-treatment of produced water (Semblante et al., 2018). Antiscalants are also widely used chemicals in cleaning circuits but little is known about their ecotoxicological effects on the receiving biota, despite their wide use (Marques et al., 2023).

In this context, the purpose of our study is to assess the impact of brine discharges from seawater desalination on the marine ecosystem of the Kahrama desalination plant. Several physical and chemical parameters of the raw seawater and brine wastewater will therefore be assessed. In addition, and for the first time in Algeria, *in situ* observations were conducted by snorkeling on the seabed.

Materials and methods

The study area

Kahrama is a joint stock company 100% owned by the company Sonatrach (Oil and Gas Company) created in 2002 by Algerian Energy Company (AEC) and put into action in September 2005. It is ISO certified (9001, 14001 and 18001 defining a system of integrated quality, safety, hygiene and environment management) whose objective is the production of electricity (2.7 million MWh) and distilled water from seawater. The complex is located in the industrial complex area of Arzew near the port of Bethioua, 40 km from the city of Oran (West Algeria) at coordinates 35°48’26.208” North and

0°14’48.911” West (*Fig. 1*). This station aims to produce water intended for human consumption, using the staged flash distillation technique or MSF (Multi Stage Flash) with a capacity of 90,000 m^3/day.

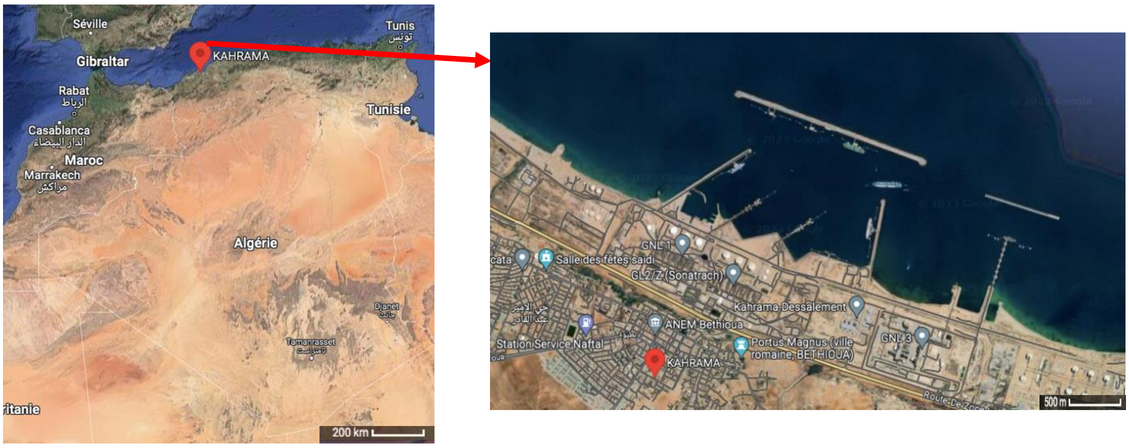

Figure 1. *Geographic location of Kahrama station (Google Maps, 2023)*

The Kahrama complex is essentially composed of:

(a) The power plant is made up of three turbo-generator groups, the 3 groups are identical each is equipped with an axial air flow compressor providing compressed air for the combustion of the gas in the turbine, which in turn drives the generator, thus developing a power of 114.6 MW. For the operation of the power plant, two systems are necessary: The fuel gas conditioning system (quality, temperature and pressure) and the electrical system for the control, monitoring and distribution of electrical energy.

(b) The desalination plant also consists of three units, seawater intake, a desalinated water treatment system and a discharge system. This complex also has a steam system made up of three heat recovery boilers connecting the power plant and the desalination plant.

The desalination of seawater process using the Multi Stage Flash or MSF technique consists of four stages (Gacem et al., 2012): seawater intake with filtration and pumps, pre-treatment by the addition of biocidal compounds, the desalination process itself and post-treatment. Briefly, the seawater is heated in a boiler, there is condensation of the steam on a bundle of pipes conveying the seawater which passes through the boiler (phase 1) (*Fig. 2*). This heated seawater then flows into another tank corresponding to another floor where the ambient pressure is lower so that the water immediately begins to boil. The sudden introduction of heated water at each stage triggers expansion and its instantaneous evaporation (“Flash”) (phase 2). Typically, only a small fraction of this water is converted to steam, depending on the pressure maintained upstairs since it will boil until the water drops back to boiling point. During the condensation process (phase 2), the steam releases its latent heat to the seawater in the pipes. The distillate in stage 1 then flows into stage 2 and together with that of stage 2, flows to stage 3 and so on. The distillate from all stages is finally collected in a distillate tank (phase 3). The latter is then transported elsewhere where it will be treated by the distilled water treatment system to end up in the drinking water system (phase 4). The brine must be recovered at the end of desalination in order to be recycled or released directly into the sea.

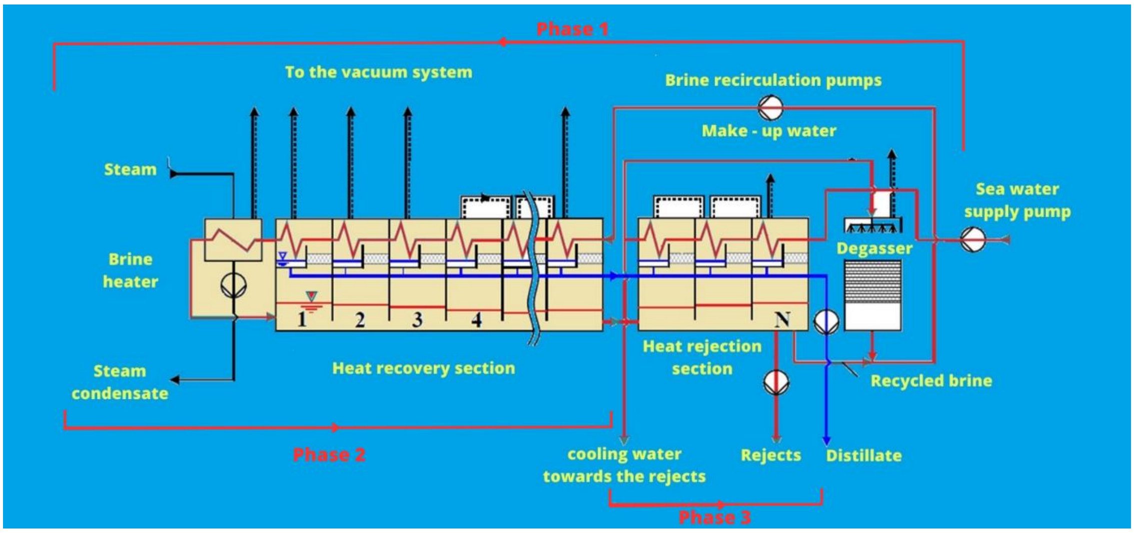

Figure 2. *Operating principle of the desalination unit at the Kahrama station*

Sample collection

To study the physicochemical parameters, seven separate water samples were taken at intervals of 4 days during the month of April 2022 from the seawater found in the reception tank belonging to the desalination station and from the discharge water consisting of brine after desalination, which were also taken from the desalination plant.

Analysis of samples

A range of physical and chemical parameters were measured. The pH, the temperature and the conductivity which is linked to the concentration and nature of the dissolved substances are measured by a conductivity meter (WTW conductivity meter inoLab Cond 7110) and are expressed in micro Siemens per centimeter µS/cm. The total hardness (TH), measured using the Metrohm 848 Titrino plus and corresponding to the overall quantity of calcium and magnesium salts, was calculated as follows:

$$\mathrm{TH} = 2.497 \times \mathrm{Ca2} + \text{concentration (mg/L)} + 4.116 \times \mathrm{Mg2} + \text{concentration (mg/L)} \qquad \text{(Eq.1)}$$

The salinity representing the mass in grams of solid substances in 1 kg of water was measured by a salinometer (Guideline instruments 8400B Autosal Lab Salinometer). The total dissolved solid matter (TDS), representing the total concentration of substances dissolved in water, composed of mineral salts such as cations and anions as well as some organic matter, was determined by the gravimetric method according to this formula:

$$\text{Total dissolved solid matter (mg/L)} = [(P2-P1)/V] \times 106 \qquad \text{(Eq.2)}$$

where P2 is the weight of the dry residue and the evaporation capsule in mg, P1 is the weight of the evaporation capsule in mg, V represents the volume of the sample (100 ml) and 106 is the reaction factor.

The alkalinity (unlike acidity) of water corresponds to the presence of bases and salts of weak acids. Its dosage was carried out by the titration method with the strong acid, hydrogen chloride, at the endpoint at pH = 4.23 using a “METROHM” device and according to this formula:

$$\text{Alk (mg/L)} = \text{VHCL (ml)} \times 10 \qquad \text{(Eq.3)}$$

where 10 is the reaction factor.

Chlorides (Cl^-) are salts, but in very variable proportions can be present in large quantities in seawater following industrial pollution. The concentration was calculated following this formula:

$$Cl^- \text{ (mg/L)} = \text{V (ml)} \times 35.5 \qquad \text{(Eq.4)}$$

where V is the Volume of silver nitrate necessary for titration of the solution and 35.5 is the reaction factor.

Calcium (Ca^{2+}) is present in particular in limestone rocks in the form of carbonate. Its salts are present in almost all natural waters. The concentration was calculated following this formula:

$$Ca^{2+} \text{ (mg/L in } CaCO_3) = \text{V (ml)} \times 50 \qquad \text{(Eq.5)}$$

where V is the volume of EDTA and 50 is the reaction factor.

Magnesium (Mg^{2+}) is present in the form of carbonates or bicarbonates in seawater. The magnesium concentration is calculated by a formula making the connection with calcium.

The iron (Fe^{3+}) is generally found in ferric and precipitated form, often associated with suspended matter. Its dosage was carried out using a mini-1240 UV-type spectrophotometer and is expressed in mg/L.

The copper ($Cu2^+$), its presence follows the erosion of soil or rocks or even the activities of processing plants. Its dosage was made by spectrophotometry at 560 nm and is expressed in mg/L.

The dissolved oxygen is related to the quantity of oxygen which is in solution in water and which is available for plant and animal respiration. Its measurement was carried out using an oximeter and is expressed in mg/L.

The dosage of hydrocarbons, an indicator of the presence of oil, has been done by gas phase chromatography and expressed in parts per million (ppm) or in mg/L (Rodier, 2010; (Bessenasse and Filali, 2014; Mehtougui et al., 2018).

In situ study

Observations were carried out by free diving in pairs, at the brine discharge area of the Kahrama desalination station at coordinates 35°48’3.348” North and 0°10’22.079” West (*Fig. 3B*), with a depth level of 1–3 m deep, in very favorable weather conditions. Photographs were taken using a waterproof digital camera (GoPro HERO 7 black Touch Screen 4K HD Video 12MP model). As a healthy control zone, we chose the Cap Carbon zone, 18 km away from the Kahrama industrial zone (*Fig. 3A*). The Cap Carbon Zone is located in the extreme west of the Gulf of Arzew, at coordinates 35°54’7.62”North and 0°20’22.31”West (*Fig. 3C*). We also used C-MAP application for the maritime map and Windy for the meteorological application (wind direction and power, sea currents, swell and water temperature).

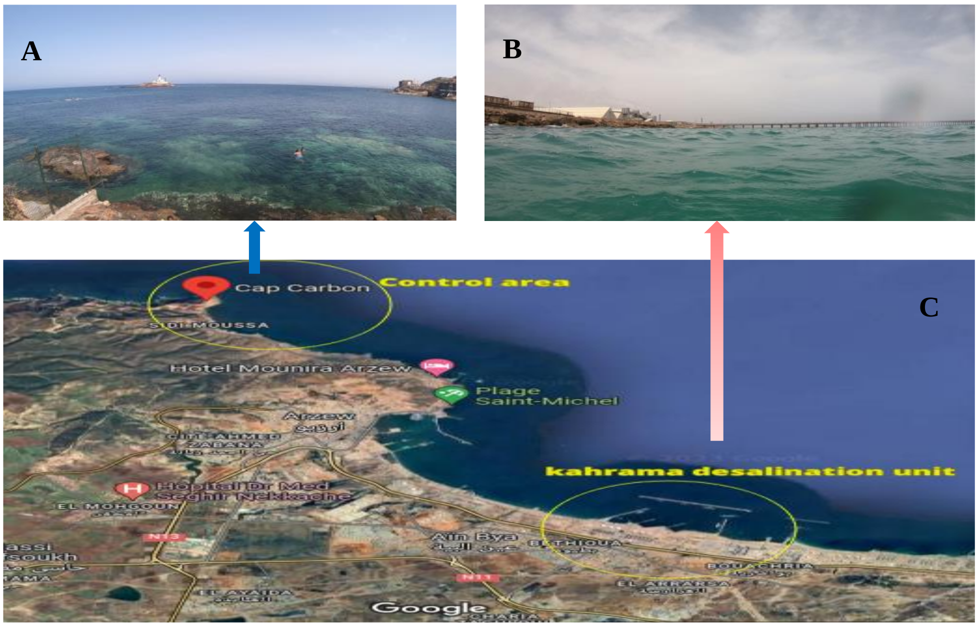

Figure 3. *Geolocation of the control area of Cap Carbon (A) and the Kahrama desalination unit (B)*

Statistical analysis

Data were analyzed with SPSS 26.0 software. For the comparison of the physicochemical parameters of the seawater (before desalination) and the discharge water (after desalination), the T-test for paired samples was used. The T-test for one sample was used to compare the parameters of the discharge water with the international standards. Statistical significance was assumed for p-values less than 0.05.

Results and discussion

The physicochemical parameters evaluation

The work carried out in this study focused on the consequences of the discharge of brine, resulting from the desalination of seawater at the Kahrama station, on the marine ecosystem. The comparative results of the physicochemical parameters of seawater and wastewater are presented in *Table 1*. The majority of the parameters studied show a p-value ≤ 0.003 except for the metals iron and copper, which proves a significant difference before and after the desalination of seawater. Indeed, pH analysis shows an average pH of 8.05 for seawater (*Table 1*). This value can be explained by the fact that the addition of CO_2 to the seawater by respiration or by oxidation of the organic matter favors the formation of carbonic acids, hydrogen ions and bicarbonate ions (Mondragón-Díaz et al., 2022). The discharge water has a pH of 8.3, which is in line with the standard limited to 9 with $p < 0.001$ (*Table 2*).

Our results concerning conductivity show an average value of 54369.14 ± 158.00 µS/cm for seawater, due to a high concentration of minerals. This value increases significantly ($P \leq 0.05$) in discharge water to 60528.57 ± 111.27 µS/cm (*Table 1*) and largely exceeds the international standard required at 2800 µS/cm which agrees with the P value < 0.001 (*Table 2*).

Table 1. *Physicochemical parameter comparison between seawater and discharge water from the Kahrama plant*

Parameters	Seawater								Discharge waters								P value
	S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**Mean±SD**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**Mean±SD**	
pH	8.2	8.07	7.99	8	8	8.1	8	**8.02±0.08**	8.6	8.3	8.32	8.3	8.28	8.26	8.28	**8.33±0.12**	P<0.001
Conductivity (µS/cm)	54210	54500	54134	54540	54300	54400	54500	**54369.14±158.00**	60700	60400	60600	60500	60600	60400	60500	**60528.57±111.27**	P<0.001
Temperature (°C)	21.5	21.6	20	20.1	20.1	21	21.2	**20.79±0.70**	27.8	28.6	27.2	26.2	27.4	27.2	27.3	**27.39±0.72**	P<0.001
Salinity (mg/L)	37250	36300	37400	36800	37100	37300	37550	**37100±425.25**	41200	41000	40300	41000	41000	41200	41600	**41042.86±390.97**	P<0.001
Total dissolved salts (mg/L)	39030	39240	39245	39096	39160	38970	39240	**39140.14±111.33**	47340	45680	47260	47190	46300	47110	47260	**46877.14±635.84**	P<0.001
Alkalinity (mg/L)	120	122	120	124	122	120	121	**121.29±1.50**	1200	1200	1200	1200	1000	1100	1000	**1128.57±95.12**	P<0.001
Total hardness (mg/L)	5010	5050	6150	6000	6100	6000	6500	**5830±571.96**	12800	12850	12900	12350	13000	13350	13200	**12921.43±319.97**	P<0.001
Chloride (mg/L)	9500	9575	9585	9230	9585	9600	9570	**9520.71±132.21**	12425	11715	11650	11005	11650	11650	11264	**11622.71±440.58**	P<0.001
Calcium (mg/L)	1000	1475	1000	1400	1450	1000	1250	**1225±222.20**	2525	3750	2375	2550	2959	3250	3000	**2915.57±482.27**	P<0.001
Magnesium (mg/L)	867.92	868.72	886.95	886.9	868.72	850.5	820.12	**864.26±23.16**	1220	1158.42	1448.88	2059.42	1959.18	1269.67	1385.1	**1500.10±362.34**	P<0.001
Iron (mg/L)	0	0	0	0	0	0.1	0.03	**0.02±0.04**	0.01	0	0	0	0.01	0	0	**0.00**	p=0.285
Copper (mg/L)	0	0	0	0	0.02	0	0	**0.00**	0	0	0	0.1	0	0	0	**0.00**	p=0.476
Hydrocarbon (mg/L)	71	70	70	71	70	70	71	**70.43±0.53**	9.6	9.5	9.7	9.6	9.7	9.5	9.7	**9.61±0.09**	P<0.001
Dissolved oxygen (mg/L)	8.46	8.5	8.4	8.4	8.5	8.5	8.47	**8.46±0.04**	9.75	7.6	7.76	7.6	7.7	7.55	7.65	**7.94±0.80**	P<0.001

Mean ± SD (n = 7), S: Sample

Table 2. *Physicochemical parameter comparison between discharge water from the Kahrama plant and their international standard values*

Parameters	Discharge waters								DWSt	P value
	S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**Mean ± SD**		
pH	8.6	8.3	8.32	8.3	8.28	8.26	8.28	**8.33 ± 0.12**	**9**	P < 0.001
Conductivity (µS cm^{-1})	60700	60400	60600	60500	60600	60400	60500	**60528.57 ± 111.27**	**2800**	P < 0.001
Temperature (°C)	27.8	28.6	27.2	26.2	27.4	27.2	27.3	**27.39 ± 0.72**	**25**	P < 0.001
Salinity (mg/L)	41200	41000	40300	41000	41000	41200	41600	**41042.86 ± 390.97**	**35500**	P < 0.001
Total dissolved salts (mg/L)	47340	45680	47260	47190	46300	47110	47260	**46877.14 ± 635.84**	**27750**	P < 0.001
Alkalinity (mg/L)	1200	1200	1200	1200	1000	1100	1000	**1128.57 ± 95.12**	**2030**	P < 0.002
Total hardness (mg/L)	12800	12850	12900	12350	13000	13350	13200	**12921.43 ± 319.97**	**4439.6**	P < 0.001
Chloride (mg/L)	12425	11715	11650	11005	11650	11650	11264	**11622.71 ± 440.58**	**21431**	P < 0.001
Calcium (mg/L)	2525	3750	2375	2550	2959	3250	3000	**2915.57 ± 482.27**	**200**	P < 0.001
Magnesium (mg/L)	1220	1158.42	1448.88	2059.42	1959.18	1269.67	1385.1	**1500.10 ± 362.34**	**820**	P = 0.003
Iron (mg/L)	0.01	0	0	0	0.01	0	0	**0.00 ± 0.00**	**3**	p = 0.285
Copper (mg/L)	0	0	0	0.1	0	0	0	**0.00 ± 0.00**	**0.5**	p = 0.476
Hydrocarbon (mg/L)	9.6	9.5	9.7	9.6	9.7	9.5	9.7	**9.61 ± 0.09**	**10**	P < 0.001
Dissolved oxygen (mg/L)	9.75	7.6	7.76	7.6	7.7	7.55	7.65	**7.94 ± 0.80**	**8**	P < 0.001

Mean ± SD (n = 7), DWSt: Discharge waters Standard values

Concerning the temperature, the seawater displays an average value of 20.7°C while that of the wastewater reaches a higher value of 20.79 ± 0.70°C but slightly exceeding the Algerian standard set at 25°C, which proves that these waters are cooled before being discharged into the sea.

The salinity is higher in the discharge waters (41042.86 ± 390.97 mg/L) made up of brines and exceeds significantly ($P \leq 0.05$) the standard set at 35500 mg/L (*Table 2*), which means that the discharge water is not diluted before its discharge into the sea.

Concerning the measurement of alkalinity and the dosage of TDS, the discharge water displays a considerable increase in these parameters following the presence of alkaline species and dissolved salts in high concentrations in brine, compared to those in seawater. Similar results were reported by Mohammedi et al. (2013) in their study of discharge from the Cap Djinet desalination plant in the province of Boumerdes (central Algeria), which is equipped with the same technology as Kahrama.

As for the analysis of the main ions such as chlorides, calcium and magnesium, our results show that seawater is rich in these ions and that their concentration increases in discharge water ($p < 0.001$ for chlorides and calcium and $p = 0.003$ for magnesium). These results are in agreement with those of Mehtougui et al. (2018) on the monitoring of discharges from the Honaine desalination plant (western Algeria). However, the use of biocide as a disinfectant here, sodium hypochlorite during the pre-treatment of seawater, can be found in the form of residual chlorine in the rejected brine and form on contact with seawater toxic complexes such as bromoform (Taylor et al., 2006).

Our results show a chloride value (11622.71 ± 440.58 mg/L) lower than that required by the international standard (21431 mg/L). Likewise, the use of antiscalants during desalination leads to an increase in these calcium ions in the washing water (Shokri and Sanavi Fard, 2023; Prisciandaro et al., 2019). The latter greatly exceeds the international standard limited to 200 mg/L. Furthermore, given the correlation that exists between total hardness and calcium and magnesium, a reduction or increase in the latter necessarily implies a reduction or increase in hardness. Our results shown in *Table 1* show a significant increase in these ions in the wastewater. Furthermore, we also measured metals such as iron and copper, our results indicated in *Table 1* show a very tiny quantity, almost zero, of these metals both in seawater and in wastewater, which explains p-value = 0.285 for iron and 0.476 for copper. The same finding has been reported in the literature (Cherif and Belhadj, 2018; Gurreri et al., 2020).

Concerning hydrocarbons, they display a value of 70.5 mg/L in seawater but without exceeding the Algerian standard equal to 120 mg/L. On the other hand, the discharge water displays a value of 7.5 mg/L complies with the Algerian standard equal to 10 mg/L. Finally, the dosage of dissolved oxygen shows a value of around 7.6 mg/L both in seawater and at the level of discharge water and not exceeding the required standard equal to 8 mg/L with $p < 0.001$. The hydrocarbon content is a crucial parameter in the sanitation of the marine ecosystem, regardless of its location or purpose (Djoher et al., 2020). It is widely accepted that the physicochemical quality of the discharged water from the desalination factories has a significantly negative impact on the aquatic life unless it is subject to stringent purification in order to comply with environmental standards (Dairi et al., 2023).

In situ study of the impact of discharge water on the studied marine ecosystem

In the Kahrama discharge area, where this study was conducted for the first time in Algeria, we were able to see a layer of foam and dirt on the water's surface that was caused by brines and washing water. These latter ones do, in fact, include various chemical substances used in the pre-treatment and maintenance of the installations, such as anti-foams and antiscalants. *Figure 4* shows the cloudy, suspended-particle-filled interior of the sea. These observations support our results from above regarding the high calcium and TDS levels in the discharge water (*Table 1*). It has also been demonstrated that antiscalants made of polyphosphonates and polymers, which are used in the desalination industry, have an effect on the physiology of the coral *Montipora capricornis* and lessen the abundance of endosymbiotic algae (Marques et al., 2023).

***Figure 4.** The presence of foam on the surface of seawater loaded with particles suspended in the sea at the discharge zone*

These chemicals can also seep into the soil, causing pollution and upsetting the balance of the marine ecosystem. For the vast majority of them, both their future and effects, as well as their unrestricted use, are poorly understood (Câmara et al., 2021).

Our observations further revealed meadows of the same species of green algae on the seafloor (at a depth of about 3 m) (*Fig. 5A*), which were strikingly similar to the green algae *Caulerpa prolifera* identified in the northern Mediterranean coasts by Perreira (2015) (*Fig. 5B*) and in Turkish coasts by Okudan et al. (2016) (*Fig. 5C*). Until recently, *Caulerpa prolifera* (Forssk.) Lamouroux was the only species of the genus *Caulerpa* present on Algeria’s coasts but since then, the species *Caulerpa taxifolia* (M. Vahl) Agardh and *Caulerpa racemosa* var. *cylindracea* (Sonder) have been reported in the northern Mediterranean (Bentaallah and Kerfouf, 2013).

A few small clusters of brown algae coexisted with this species of green algae in the Kahrama discharge area; no other species of seagrass were found. However, we noticed that as it approaches the brine discharge zone (*Fig. 6*), the expansive green algae (*Fig. 7*) covering the rocky and sandy bottoms gradually disappears.

This decrease in vegetation is probably caused by the green algae beds’ sensitivity to an increase in the salinity of the environment around brine discharges. In fact, as shown in *Figure 8*, an atrophy in the leaves of these algae was noticed. *Posidonia oceania*, a marine phanerogam native to the Mediterranean Sea, demonstrated this when it experienced oxidative damage as a result of brine discharge from desalination stations (Capo et al., 2020). While *Cymodocea nodosa* and other Mediterranean seagrasses are more resilient to the effects of hypersalinity stress (Sandoval-Gil et al., 2012).

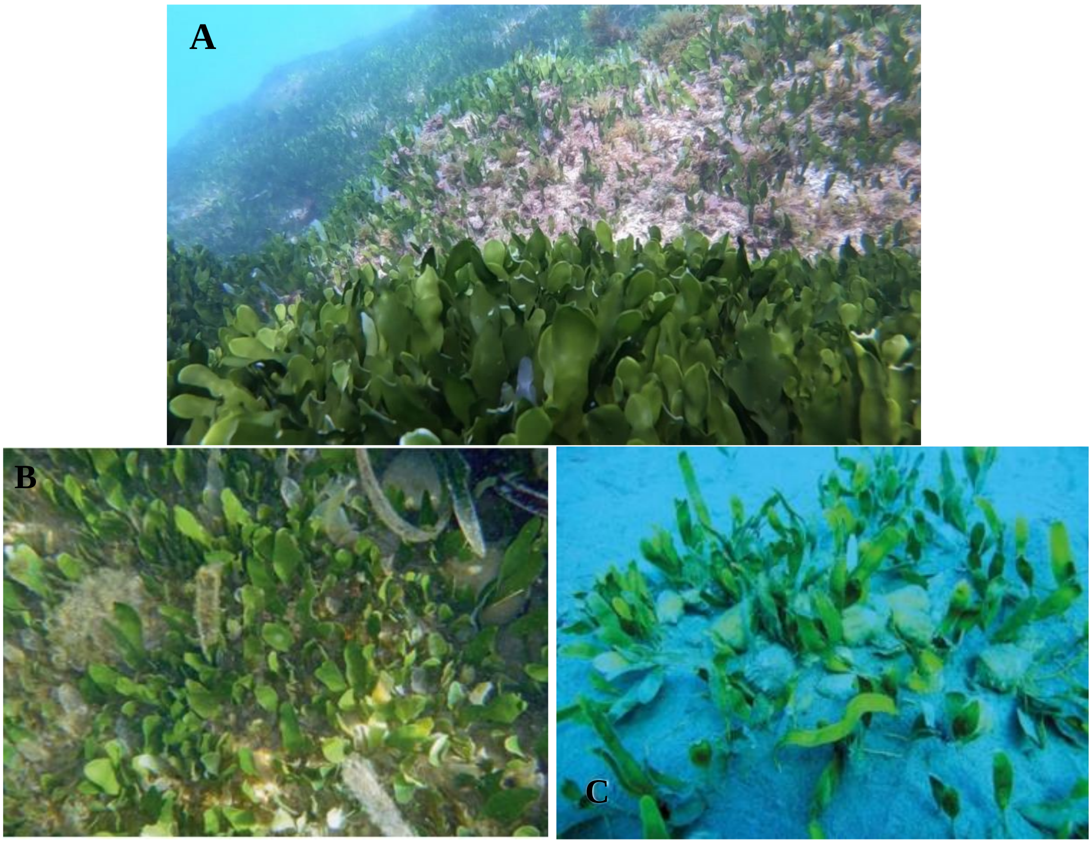

Figure 5. *Green algae (Caulerpa prolifera), phenotypically observed, in the brine discharge of Kahrama area (A), Perreira's (2015) identification (B), Okudan's et al. (2016) identification (C)*

Figure 6. *Observation of green algae beds in the sandy and rocky bottoms at the brine discharge zone in the Kahrama area*

As we moved deeper into the brine discharge zone, we noticed a rocky area that was overrun with sea urchins but devoid of any vegetation (*Figure 9A*, *B*). Even though sea urchins are sensitive to sudden changes in salinity, their abundance in polluted areas is caused by their herbivorous nature. Their presence is a sign of pollution in a coastal zone (Parra-Luna et al., 2020; Zhang et al., 2020).

Figure 7. *Progressive decrease in benthic flora in the brine discharge zone in the Kahrama area*

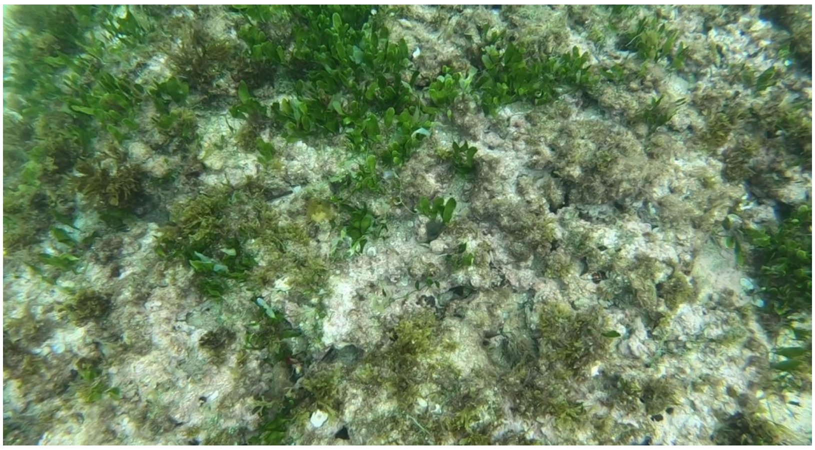

Figure 8. *Atrophy of green algae leaves due to sensitivity to the hypersaline environment in the brine discharge zone of Kahrama area*

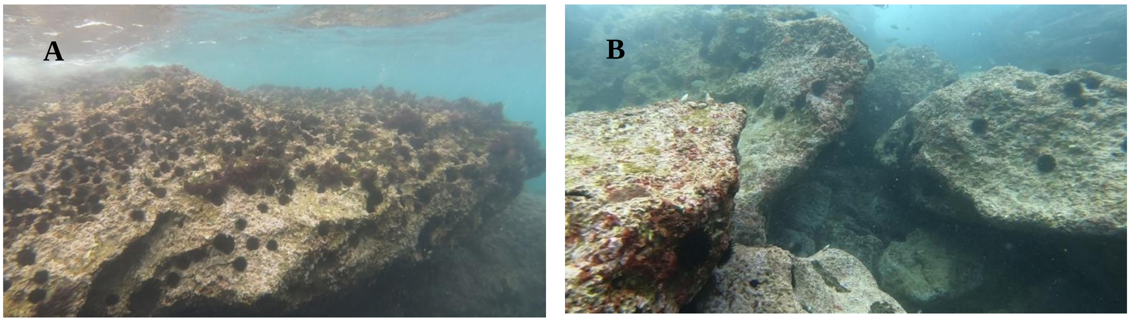

Figure 9. *Strong presence of sea urchins occupying the rocky bottoms in the brine discharge zone of Kahrama*

Indeed, different bioindicators have been used extensively by researchers until now to assess the quality of the marine environment (Fouad et al., 2019). Those from benthic macro-fauna have many advantages. Echinoderms, corals, marine worms and molluscs

DOI: http://dx.doi.org/10.15666/aeer/2202_12811295

represent the most used organisms (Adzigbli and Yuewen, 2018). However, the pollution caused by brine discharge risks contaminating the vital organs of these sea urchins. Indeed, an accumulation of contaminants was observed in the eggs/gonads of the sea urchin *Paracentrotus lividus* (Lamarck, 1816), collected on the northwest Portuguese coast subject to anthropogenic pressures, but taking into account the low levels of accumulated products, the harvested sea urchins were declared safe for human consumption (Rocha et al., 2017). Another study, in Corsica (north-west Mediterranean, near the old Canari asbestos mine) on *Paracentrotus lividus* showed that contamination by trace elements, coming from the migration of mining waste, does not affect the health of *Paracentrotus lividus* (El Idrissi et al., 2023). Furthermore, our results obtained in the statistical study, during the determination of iron and copper in the brine discharge water, showed an absence of these elements in the environment.

Finally, and in order to evaluate the extent of this pollution generated by the water from brine discharges at the level of the industrial zone of Kahrama, where swimming is prohibited, the latter was compared with a more distant zone, authorized for swimming, the Cap Carbon beach. Our observations showed a totally healthy environment, with clear and luminous water revealing a variety of small fish and lush flora composed of different seagrass beds (*Figs. 10* and *11*).

***Figure 10.** Marine fauna and flora observed (at 1 m depth) at the healthy control zone of Cap Carbon (Arzew, Algeria)*

***Figure 11.** Lush benthic flora observed at the healthy control zone of Cap Carbon (Arzew, Algeria)*

Conclusion

These findings lead us to the conclusion that building a desalination station has a variety of environmental effects, some of which are beneficial, like the availability of high-quality water, which is a prerequisite for economic and social development. Others are detrimental, such as marine pollution which destabilizes and unbalances marine ecosystems, leading to the decrease of plankton biomass and marine biodiversity. In addition, before brine is released into the environment, a brine neutralization station should be taken into consideration in order to preserve the Mediterranean coast's ecological health. An important thing to consider is that the salts produced by the desalination sectors can be recovered in some industries, like construction or glass manufacturing, or used again internally on the producing site. Finally, in order to restore the original conditions of various ecosystems, this study may be used to increase awareness of the harm that these pollutants cause.

REFERENCES

[1] Adzigbli, L., Yuewen, D. (2018): Assessing the impact of oil spills on marine organisms. – Journal of Oceanography and Marine Research 6(179): 472-9.

[2] Bentaallah, M. E.-A., Kerfouf, A. (2013): Prolifération de l'algue *Caulerpa racemosa* dans les écosystèmes littoraux de l'Algérie: état des lieux et des connaissances. – Géographie Physique et Environnement 7(1): 157-164.

[3] Bessenasse, M., Filali, M. B. (2014): Impact du dessalement sur l'environnement en Algérie. – Agrobiologia 6: 75-81.

[4] Câmara, J. S., Montesdeoca-Esponda, S., Freitas, J., Guedes-Alonso, R., Sosa-Ferrera, Z., Perestrelo, R. (2021): Emerging contaminants in seafront zones. Environmental impact and analytical approaches. – Separations 8(7): 95.

[5] Capo, X., Tejada, S., Ferriol, P., Pinya, S., Mateu-Vicnes, G., Box, A., Sureda, A. (2020): Hypersaline water from desalinization plants causes oxidative damage in *Posidonia oceanica* meadows. – Science of the Total Environment 736: 139601.

[6] Cherif, H., Belhadj, J. (2018): Environmental Life Cycle Analysis of Water Desalination Processes. – In: Gnaneswar Gude, V. (ed.) Sustainable Desalination Handbook. Butterworth-Heinemann, Oxford, pp. 527-559.

[7] Dairi, S., Mrad, D., Bouamrane, A., Djebbar, Y., and Abida, H. (2023): Wastewater reclamation and reuse trends in Algeria: opportunities and challenges. – Doklady Earth Sciences 511: 753-760.

[8] Djoher, A. (2020): Desalination projects in Algeria: what are the environmental and economic issues of seawater desalination? – Environment and Ecology Research 8(3): 59-69.

[9] El Idrissi, O., Ternengo, S., Monnier, B., Lepoint, G., Aiello, A., Bastien, R., Lourkisti, R., Bonnin, M., Santini, J., Pasqualini, V., Gobert, S. (2023): Assessment of trace element contamination and effects on Paracentrotus lividus using several approaches: pollution indices, accumulation factors and biochemical tools. – Science of the Total Environment 869: 161 686.

[10] Elsaid, K., Sayed, E. T., Abdelkareem, M. A., Mahmoud, M. S., Ramadan, M., Olabi, A. G. (2020): Environmental impact of emerging desalination technologies: A preliminary evaluation. – The Journal of Environmental Chemical Engineering 8(5): 104099.

[11] Fouad, M., Bessi, H., Benhra, A., Bouhallaoui, M. (2019): The benthic community used as bioindicator for assessment of the quality of a Moroccan coastal ecosystem: Moulay Bousselham Lagoon. – International Journal of Engineering Research & Technology 8(3) 127-133.

[12] Gacem, Y., Taleb, S., Ramdani, A., Senadjki, S., Ghaffour, N. (2012): Physical and chemical assessment of MSF distillate and SWRO product for drinking purpose. – Desalination 290: 107-114.

[13] Gurreri, A., Tamburini, A., Cipollina, A., Micale, G. (2020): Electrodialysis applications in wastewater treatment for environmental protection and resources recovery: A systematic review on progress and perspectives. – Membranes 10(7): 146.

[14] Kara, O., Khaldi, A. (2017): Desalination of seawater and environmental impacts: case of El Mactaa station. – Journal of Water and Environmental Sciences 1(2): 249-253.

[15] Lior, N. (2017): Sustainability as the quantitative norm for water desalination impacts. – Desalination 401: 99-111.

[16] Marques, J. A., Gafni, A., Adler, O., Levy, O., Bar-Zeev, E. (2023): Antiscalants used in the desalination industry impact the physiology of the coral Montipora capricornis. – Water research 2291: 119411.

[17] Mehtougui, M. S., Kerfouf, A., Ardjoum, S., Mehtougui, F. (2018): Assessment of the quality of water discharges from a desalination plant: case of Honaine station (Western Algeria). – The International Journal of Sciences: Basic and Applied Research 39: 89-95.

[18] Ministry of Water Resources (MWR) (2023): Annual Algerian report. – MWR, Algiers.

[19] Mohammedi, K., Talamali, A., Smaili, Y., Saadoun, I., Ait-Aider, A. (2013): Environmental impact of seawater desalination plants: case study in Algeria. – American Journal of Environmental Protection 2(6): 141-148.

[20] Mokrani, M. D., Moudjari, R. (2022): Energy security in Algeria: opportunities and challenges. – Finance and Business Economies Review 6(4): 266-277.

[21] Mondragón-Díaz, L. F., Molina, A., Duque, G. (2022): Influence of environmental variables on the spatiotemporal dynamics of water quality in Buenaventura Bay, Colombia Pacific. – Environmental Monitoring and Assessment 194: 720.

[22] Okudan, E. S., Dural, B., Demir, V., Erdugan, H., Aysel, V. (2016): Biodiversity of Marine Benthic Macroflora (Seaweeds/Macroalgae and Seagrasses) of the Mediterranean Sea. – In: Turan, C., Salihoğlu, B., Özgür Özbek, E., and Öztürk, B. (eds.) The Turkish Part of the Mediterranean Sea; Marine Biodiversity, Fisheries, Conservation and Governance. Marine Research Foundation (TUDAV) Istanbul, pp. 107-135 (in Turkish).

[23] Panagopoulos, A., Haralambous, K. J. (2020): Environmental impacts of desalination and brine treatment-Challenges and mitigation measures. – Marine Pollution Bulletin 161: 111773.

[24] Papa, F., Crétaux, J. F., Grippa, M., Robert, E., Trigg, M., Tshimanga, R. M., Calmant, S. (2023): Water resources in Africa under global change: monitoring surface waters from space. – Surveys in Geophysics 44(1): 43-93.

[25] Parra-Luna, M., Martín-Pozo, L., Hidalgo, F., Zafra-Gómez, A. (2020): Common sea urchin (*Paracentrotus lividus*) and sea cucumber of the genus Holothuria as bioindicators of pollution in the study of chemical contaminants in aquatic media. A revision. – Ecological Indicators 113: 106185.

[26] Pereira, L. (2015): Seaweed Flora of the European North Atlantic and Mediterranean. – In: Kim, S. K. (ed.) Springer Handbook of Marine Biotechnology. Springer Handbooks. Springer, Berlin.

[27] Prisciandaro, M., Innocenzi, V., Tortora, F., Mazziotti di Celso, G. (2019): Reduction of fouling and scaling by calcium ions on an UF membrane surface for an enhanced water pre-treatment. – Water 11(5): 984.

[28] Pulido-Bosch, A., Vllejos, A., Sola, F. (2019): Methods to supply seawater to desalination plants along the Spanish Mediterranean coast and their associated issues. – Environmental Earth Sciences 78(10): 322.

[29] Rocha, C., Camacho, C., Eljarrat, E., Peris, A., Aminot, Y., Readman, J. W., Boti, V., Nannou, C., Marques, A., Nunes, M. L., Almeida, C. M. (2017): Bioaccumulation of persistent and emerging pollutants in wild sea urchin *Paracentrotus lividus*. – Environmental Research 161: 354-363.

[30] Rodier, J. (2010): Analyse de l’eau naturelle, eau de mer et eau industrielle. – Edition Dunod, Paris.

[31] Sandoval-Gil, J. V., Lazaro, M. G., Ruiz, J. M. (2012): Tolerance of Mediterranean seagrasses (*Posidonia oceanica and Cymodocea nodosa*) to hypersaline stress: water relations and osmolyte concentrations. – Marine Biology 159: 1129-1141.

[32] Semblante, G. U., Lee, J. Z., Lee, L. Y., Ong, S. L., Ng, H. Y. (2018): Brine pre-treatment technologies for zero liquid discharge systems. – Desalination 441: 96-111.

[33] Shah, K. M., Billinge, I. H., Chen, X., Fan, H., Huang, Y., Winton, R. K., Yip, N. Y. (2022): Drivers, challenges, and emerging technologies for desalination of high-salinity brines: A critical review. – Desalination 538: 115827.

[34] Shokri, A., Sanavi Fard, M. A. (2023): Comprehensive overview of environmental footprints of water desalination and alleviation strategies. – International Journal of Environmental Science and Technology 20: 2347-2374.

[35] Taylor, C. J. L. (2006): The effects of biological fouling control at coastal and estuarine power stations. – Marine Pollution Bulletin 53: 30-48.

[36] Zapata-Sierra, A., Cascajares, M., Alcayde, A., Manzano-Agugliaro, F. (2021): Worldwide research trends on desalination. – Desalination 519: 115305.

[37] Zhang, Z., Yang, W., Lin, K. B., Ding, L., Zheng, Y. Y., Zhang, G. (2020): Effects of hypersalinity on serum nonspecific immune indices in three marine organisms. – Polish Journal of Environmental Studies 29(3):2467-2474.