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The Disadvantages of Seawater Desalination at the Bousfer Station Located on the Oran Coast in Western Algeria

Scheherazede Kassouar[1*], Sidi Mohammed El-Amine Abi-Ayad[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

* Corresponding author's e-mail: sche_kass@yahoo.fr

ABSTRACT

Securing sustainable access to water resources is a critical concern for all nations bordering the Mediterranean Sea, and Algeria is no exception. Leveraging its extensive 1,200 – kilometer coastline, Algeria has embraced desalination as a key strategy, treating both seawater and brackish water sources. This approach provides potable water to inland towns and cities, extending as far as 60 kilometers from the coast. Currently, Algeria boasts an impressive network of 21 desalination plants, with a combined daily production capacity of 2.6 million cubic meters. The majority of these facilities utilize reverse osmosis, a widely employed desalination technology. This study focused on the Bousfer mini-desalination plant situated on Algeria's western coast. Various water samples were analyzed throughout the desalination process: seawater intake, post-desalination (osmosis) water, remineralized drinking water, and the resulting brine wastewater. A physicochemical and bacteriological analysis was conducted to assess water quality at each stage. Statistical comparisons were performed using paired-sample T-tests for seawater and osmosis water, and one-sample T-tests were used to compare drinking water and wastewater against established international standards. The analysis revealed significant reductions (p-value < 0.001) in most physicochemical parameters for the reverse osmosis water, including conductivity, total dissolved solids (TDS), alkalinity, total hardness, chlorides, calcium, and magnesium. Conversely, these parameters were significantly elevated in the brine wastewater. The bacteriological analysis confirmed the absence of harmful bacteria like *E. coli*, *enterococci*, and *sulphite-reducing clostridia* in the final drinking water. However, this study also highlighted a negative environmental externality, the presence of debris and foam layers on the water surface near the desalination plant outlet, attributed to chemical discharges, which poses a potential nuisance for tourists visiting nearby Bousfer beaches.

Keywords: desalination of seawater, reverse osmosis, environmental impact, Bousfer, Oran, Algeria.

INTRODUCTION

While Algeria grapples with limited natural freshwater resources and a burgeoning population, securing a sustainable water supply remains a critical challenge. This North African nation, situated in a region particularly vulnerable to climate change's impact on hydrological systems, faces even greater pressure on existing water management strategies [Papa et al., 2023; Piedra et al., 2019]. Following a global trend, Algeria has embraced desalination as a cornerstone strategy, heavily invested in reverse osmosis technology, similar to that employed by Spain, another major desalination producer bordering the Mediterranean [Khordagui, 2013]. This large-scale program has yielded significant success. As of 2024, Algeria boasts an impressive network of 21 operational desalination plants, collectively producing a daily output of 2.6 million cubic meters of water, with even more facilities under construction [MWR report, 2024]. Standing out amongst these is the Mactaa plant near Oran, which holds the title of Africa's largest seawater desalination facility. This feat underscores Algeria's advancements in membrane technologies, specifically nanofiltration (NF) and reverse osmosis (RO), leading to reduced desalination costs [Tigrine et al., 2023; Dunglas, 2014]. These efforts solidify Algeria's position as a regional leader in the fight against water scarcity. The Algerian desalination program's success story serves as a valuable example for other nations facing similar challenges, highlighting the potential of these membrane technologies to ensure water security in a world with a growing population and a changing climate

Saltwater desalination offers a solution for producing fresh water in arid regions, but it can also have unintended consequences for the marine environment [UNEP/MED program, 2017]. Two key areas of concern are the intake of seawater and the subsequent discharge of brine after desalination [Aljohani et al., 2023; Abdellah and Khaldi, 2017]. The process of drawing in seawater can result in the entrainment and collision of marine organisms, harming unsuspecting fish, plankton, and larvae [CNRC, 2008; UNEP report, 2008]. The discharged brine, a concentrated by-product, often contains a cocktail of chemicals including antifoulants, antifoams, and antiscalants used during various stages of desalination [Bessenasse & Belkacem Filali, 2014]. While antifoulants and antifoams act as biocides to prevent organism growth within the desalination system, their broader ecological impacts remain understudied [Morgan et al., 2013]. Similarly, antiscalants, widely used for cleaning desalination circuits, have received less attention regarding their potential ecotoxicity [Marques et al, 2023].

This study specifically investigates the Bousfer desalination unit on Algeria's western coast. This selection allows us to closely monitor the effects of desalination discharges on both the marine ecosystem and tourist activities at nearby Bousfer beaches. The Bousfer unit, a mini-station, produces 5,000 cubic meters of drinking water daily. This study analyzed the physicochemical and bacteriological characteristics of water samples taken at various stages of the desalination process, including seawater intake, post-osmosis water, remineralized water or final drinking water, and the resulting brine wastewater.

MATERIALS AND METHODS

Study area

The desalination unit at the Bousfer station

The Bousfer desalination plant, situated in western Algeria's Oran province (wilaya) within the commune of Bousfer, plays a vital role in supplying the region with fresh water for human consumption. Located at coordinates 35°41'13.92" North and 0°58'51.924" West, the facility occupies a footprint of 6730 square meters (Figure 1). This mini-desalination plant utilizes reverse osmosis technology to treat seawater and produce 5,000 cubic meters of fresh water daily.

Operation of the Bousfer desalination plant:

The Bousfer desalination plant relies on reverse osmosis, a widely used desalination technology [Berland et al., 2002]. In this process, seawater (the more concentrated solution) and treated freshwater (the less concentrated solution) are separated by a semi-permeable membrane. Naturally, there's a tendency for water molecules to move from the less concentrated side to the more concentrated side to achieve equilibrium. However, by applying pressure to the seawater side exceeding a critical point (osmotic pressure), the flow of water molecules is reversed. This allows for the selective passage of water molecules through the membrane, leaving the dissolved salts behind in the concentrated brine solution.

Following desalination, the treated water undergoes disinfection to ensure microbiological safety. Remineralization is then performed using a solution of carbon dioxide and lime to create

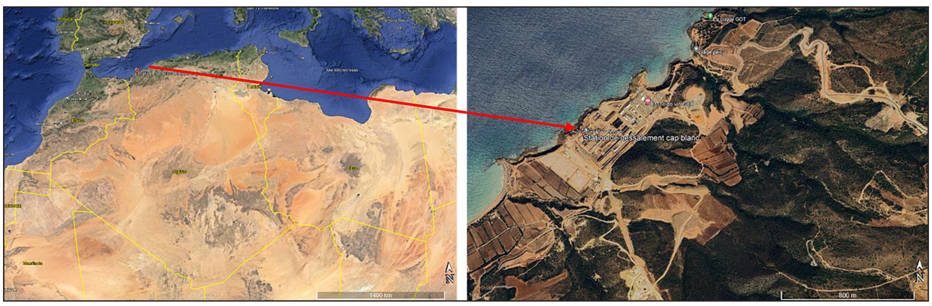

Figure 1. Geographic location of Bousfer station (Cap Blanc) (Google Maps, 2024)

calcium bicarbonate. This step increases the pH of the water and improves its palatability, making it suitable for human consumption. The process involves a fixed dose of carbon dioxide (50 mg/l) and a pH-controlled addition of lime, typically targeting a pH range of 7.8 to 8.2. Finally, the treated water is stored in a dedicated tank before distribution.

Sample collection

An assessment of the Bousfer desalination plant's water quality was conducted in May 2022. We collected and analysed seven separate samples at various time intervals for each of the following water types: seawater (drawn from the intake tank), osmosis water (post-desalination permeate), treated water (final drinking water), and wastewater (discharge brine). The focus of the analysis was on physicochemical parameters, with the average values for each water type being compared against established standards. Treated water quality was evaluated against Algerian regulations for potable water intended for human consumption [JORADP, 2011]. The discharged brine's quality was assessed against international standards. This comparative analysis aimed to identify any potential deviations from the regulatory requirements.

Analysis of samples

All samples were analysed at the control laboratory of the Bousfer desalination plant and at the laboratory of the SEOR Company (The Oran Water and Sanitation Company) as follows: the pH, the temperature and the conductivity which are 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 centimetre 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:

$$TH = 2.497 \times Ca^{2+} \text{ concentration (mg/L)} + 4.116 \times Mg^{2+} \text{ concentration (mg/L)} \quad (1)$$

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:

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

where: $P2$ – the weight of the dry residue and the evaporation capsule in mg, $P1$ – 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:

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

where: 10 – 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:

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

where: V – 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:

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

where: V – 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 (Cu^{2+}), 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. [Rodier, 2010; Bessenasse and Filali, 2014; Mehtougui et al., 2018].

Statistical analysis

Statistical analysis of the water quality data was performed using SPSS 26.0 software. To assess the effectiveness of the desalination process, a paired-samples T-test was employed to compare the physicochemical parameters of the seawater (influent) and the post-desalination reverse osmosis water (permeate). This statistical test helps determine if there's a statistically significant difference between the two water types. For the treated drinking water and the discharged brine wastewater, a one-sample T-test was used. In this case, the test compares the measured parameter values in each water type against established international standards. A statistically significant difference, indicated by a p-value less than 0.05 ($p \leq 0.05$). This approach allows us to evaluate the desalination process's efficiency in removing impurities from seawater and ensure the treated drinking water meets international potability standards, while also assessing the potential environmental impact of the discharged brine.

Bacteriological study

To evaluate the microbiological quality of the water produced by the Bousfer desalination plant, a series of tests was conducted in May 2022. Four water samples were collected at three-day intervals for each water type: seawater, post-desalination (osmosis) water, and remineralized drinking water. The analysis focused on the presence of four indicator bacteria groups: *total coliforms*, *Escherichia coli (E. coli)*, *Enterococci*, and *Clostridium*.

For *total coliform* detection, a standard technique was employed using the TTC Chapman medium on petri dishes. These dishes were incubated at 36 °C for 24 hours. The presence of total coliforms is confirmed by the appearance of yellow or orange-yellow colonies. *E. coli* detection utilized a different approach involving 3 ml of tryptophan medium in test tubes, followed by incubation at 44 °C for 24 hours. Kovacs reagent was then used to confirm the presence of *E. coli*, which would be indicated by the formation of a red ring. *Enterococci* detection relied on Slanetz and Bartley culture medium in Petri dishes incubated at 36 °C for 24 hours. The presence of *Enterococci* is identified by the appearance of red, pink, or dark brown colonies. Finally, *Clostridium* detection utilized TSC culture medium in petri dishes incubated at 37 °C for 48 hours. The formation of black colonies would confirm the presence of *Clostridium*.

RESULTS AND DISCUSSION

This study investigated the Bousfer desalination plant in Algeria, focusing on the water quality throughout the desalination process and the potential environmental impact. Both the physicochemical and bacteriological parameters of seawater, the desalinated osmosis water, the final remineralized drinking water, and the discharged brine wastewater were analysed. A key area of interest was the potential impact of brine discharge on the nearby coast and tourist activities. The desalination process utilizes reverse osmosis technology, which was also a focus of our study. By analyzing these various water samples, this study aimed to assess the effectiveness of the desalination process in producing safe drinking water while also evaluating potential environmental concerns associated with brine disposal.

Evaluation of the physicochemical parameters of seawater and osmosis water

The physicochemical analysis of the Bousfer desalination plant reveals significant reductions in most parameters following reverse osmosis treatment (Table 1). The majority of parameters exhibit a p-value ≤ 0.001, indicating a statistically highly significant difference between seawater and osmosis water.

As evident from the table, the desalination process effectively removes dissolved salts (reflected by the substantial decrease in TDS, conductivity, and chloride concentration). This aligns with the primary function of reverse osmosis in desalination, which is to generate freshwater by separating dissolved ions from seawater. The reduction in total hardness (calcium and magnesium) aligns with the removal of dissolved salts. Interestingly, the alkalinity reduction is less pronounced compared to other parameters. This might be due to the presence of bicarbonate ions (HCO_{3-}), which are not efficiently removed by reverse osmosis membranes. The pH shows a slight decrease from seawater to RO water, possibly due to the release of carbon dioxide (CO_2) from the dissociation of bicarbonate ions during desalination. Dissolved oxygen remains relatively unchanged, indicating

Table 1. Comparative analysis of the physicochemical parameters of seawater and osmosis water

Parameters	Seawater from the Bousfer plant								Reverse Osmosis water from the Bousfer plant								P-Value
	S1	S2	S3	S4	S5	S6	S7	Average	S1	S2	S3	S4	S5	S6	S7	Average	
pH	8.1	8.12	8.16	8.20	8.10	8.12	8.16	8.17	8.09	8.23	8.47	8.23	7.21	7.8	7.19	7.79	p=0.179
Conductivity (µS/cm)	55100	55300	55200	55000	55100	55900	54500	53200	820	697	705	815	729	1077	912	832	p<0.001
Temperature (°C)	20.5	19.5	19.9	19.4	18.2	19.8	19.5	19	20.1	19	19.7	19.8	20.1	20.2	20.8	20	p=0.063
Total **d**issolved Salts (mg/L)	37088	38045	38096	37960	37750	38771	38881	38044	393.6	348	356	391	349	516	437	388.7	p<0.001
Alkalinity (mg/L)	118.82	117.92	117.56	119.33	115.68	120.37	117.71	117.96	41.28	40.57	40.43	43.88	40.99	39.78	40.63	41.07	p<0.001
Total **h**ardness (mg/L)	7005.17	7362.85	7201.54	7133.90	7396.53	7296.83	7365.12	7151.41	21.87	28.41	28.42	22.15	25.42	25.88	28.95	25.17	p<0.001
Chlorides (mg/L)	20444.5	20918.75	20920.75	20915.73	19534.6	18140.35	18058.30	17830.86	241.7	240.74	240.74	239.64	230.1	240.65	238.96	236.93	p<0.001
Calcium (mg/L)	451.61	464.78	478.37	484.18	476.12	482.23	471.64	450.69	4.91	4.89	5.09	4.84	5.03	4.98	8.12	4.58	p<0.001
Magnesium (mg/L)	1428.32	1516.42	1459.45	1438.44	1517.08	1489.17	1512.19	1454	2.34	3.94	3.82	2.45	3.12	3.27	3.93	3.60	p<0.001
Iron (mg/L)	0.075	0.071	0.41	0.05	0	0.25	0.05	0.14	0	0.05	0.04	0	0	0.02	0.001	0.02	p=0.049
Copper (mg/L)	0.04	0.03	0.01	0.04	0.05	0.04	0.01	0.03	0.01	0.01	0	0.01	0.01	0	0.01	0.01	p=0.004
Dissolved oxygen (mg/L)	2.01	2.03	2.1	2.05	2.03	3.01	2.0	2.20	2.06	2.04	2.06	2.03	1.9	2.3	2.07	2.05	p=0.335

Note: S – sample (1К7).

minimal impact of the desalination process on this parameter. Overall, the physicochemical analysis suggests that the Bousfer desalination plant successfully reduces the salinity of seawater using reverse osmosis. It's important to note that while iron and copper were not statistically significant at the $p \leq 0.001$ level, their concentrations also decreased following desalination. Here's a table summarizing the key findings (excluding iron and copper due to p-value > 0.001):

Analysis of physicochemical parameters of drinking water compared to international standards

The analysis of the remineralized drinking water produced by the Bousfer desalination plant revealed compliance with most international physicochemical drinking water standards (Table 3). The average pH of 7.80 falls within the acceptable range, as international standards typically limit pH to a maximum of 9. The measured conductivity of 1040 µS/cm stays well below the standard of 2800 µS/cm. The average drinking water temperature of 20.1 °C is not a point of concern. These parameters (500.1 mg/L for TDS, 63.10 mg/L for alkalinity, and 117.53 mg/L for total hardness) adhere to current international regulations (Table 3). The chloride concentration, however, shows a minor exceedance. The average value of 272.60 mg/L is slightly above the recommended standard of 200 mg/L. The measured levels of calcium (35.40 mg/L) and magnesium (6.60 mg/L) comply with established standards (Table 3). Iron and copper concentrations in the drinking water were within permissible limits according to international regulations. The average dissolved oxygen level of 1.82 mg/L meets the requirement of 5 mg/L. Overall, the physicochemical analysis indicates that the Bousfer desalination plant

Table 2. Percent change of seawater and reverse osmosis water physicochemical parameter

Parameter	Seawater	Reverse osmosis water	Percent change (%)
pH	8.17	7.79	4.65
Conductivity (µS/cm)	53200	832	98.44
TDS (mg/L)	38044	388.7	98.98
Total hardness (mg/L)	7151.41	25.17	99.65
Alkalinity (mg/L)	117.96	41.07	65.18
Chlorides (mg/L)	19000.86	236.93	98.75
Calcium (mg/L)	450.69	4.58	98.98
Magnesium (mg/L)	1454	3.6	99.75
Dissolved oxygen (mg/L)	2.18	2.15	1.38

Table 3. Analysis of physico-chemical parameters in drinking water from the Bousfer plant

Parameters	Drinking water from the Bousfer plant								Dst	P-value
	S1	S2	S3	S4	S5	S6	S7	Average		
pH	8.37	8.18	8.23	7.59	8.38	7.52	7.17	7.80	6.5 - 9	p=0.666
Conductivity (µS/cm)	1006	1031	1039	1053	1077	1079	1087	1040	2800	p<0.001
Temperature (°C)	19.7	19.1	19.9	20.4	20.8	20.9	21	20.1	25	p<0.001
Total dissolved salts (mg/L)	482	497	518	517	497	506	530	500.1	1000	p<0.001
Alkalinity (mg/L)	66.25	65.6	63.46	54.24	68.29	64.14	61.82	63.10	500	p<0.001
Total hardness (mg/L)	107.21	167.85	120.60	114.50	111.20	115.97	103.60	117.53	500	p<0.001
Chlorides (mg/L)	297.65	298.66	297.46	295.30	297.41	247.32	247.35	272.60	200	p<0.001
Calcium (mg/L)	48.61	35.20	35.70	35.77	34.35	31.26	35.29	35.40	200	p<0.001
Magnesium (mg/L)	4.78	6.82	11.3	5.71	6.51	6	5.92	6.60	150	p<0.001
Iron (mg/L)	0	0	0	0.03	0.01	0.03	0	0.01	0.3	p<0.001
Copper (mg/L)	0	0.01	0.01	0	0	0.00	0.01	0.01	2	p<0.001
Dissolved oxygen (mg/L)	1.96	2	2.01	2	2	1.68	2.05	1.82	5	p<0.001

Note: S – sample (1–7), Dst – drinking water standard value.

produces drinking water that meets most international quality standards.

Comparative study of the physicochemical parameters of seawater and waste water

The analysis of the discharged brine wastewater (Table 4) revealed significantly higher concentrations of several parameters compared to raw seawater. Both TDS and conductivity exhibited increases in the brine discharge, reflecting the higher concentration of dissolved ions compared to seawater. Chloride concentration also rose in the brine, likely due to factors like the use of sodium hypochlorite (NaClO) during pretreatment. The presence of antiscalants used during desalination might explain the elevated levels of calcium ions observed in the brine. These findings

Table 4. Comparison of seawater parameters to discharge water parameters from Bousfer Plant

Parameters	Seawater from Bousfer plant							Discharge water from Bousfer plant							P value
	S1	S2	S3	S4	S5	S6	S7	S1	S2	S3	S4	S5	S6	S7	
pH	7.99	8.07	8.2	8	8.1	8.0	8.6	8	8.3	8.31	8.3	8.29	8.28	8.27	P<0.001
Conductivity (µS/cm)	54000	54500	54540	54134	54400	54300	56500	58700	60500	60700	60600	60500	60500	60400	P<0.001
Temperature (C°)	21	21.6	20.5	20.1	21	20.1	21.2	27.6	28.8	27	26.4	27.2	27.4	27.1	P<0.001
Salinity (mg/L)	38250	37300	37100	37300	37400	36800	37550	41000	41200	40100	43000	41600	41300	41000	P<0.001
Total dissolved salts (mg/L)	39040	39250	39255	39086	39160	39240	38960	47440	46680	47160	47290	47000	47260	47110	P<0.001
Alkalinity (mg/L)	122	120	124	120	121	120	120	1220	1300	1200	1100	1300	1200	1100	P<0.001
Total hardness (mg/L)	5060	5040	5150	5900	6000	6100	6400	13800	1850	13900	12850	13040	13250	13300	P<0.001
Chloride (mg/L)	8900	9175	9485	9330	9685	9650	9775	15425	15715	15650	15005	15650	15650	15264	P<0.001
Calcium (mg/L)	1200	1470	1100	1300	1350	1200	1250	2525	3750	2375	2550	2959	3250	3300	P<0.001
Magnesium (mg/L)	867.92	878.72	896.95	866.9	858.72	860.5	840.12	1160	1158.42	1548.88	2079.42	1950.2	1367.55	1385.70	P<0.001
Iron (mg/L)	0	0.01	0.03	0	0	0	0	0	0	0	0.01	0	0	0	p=0.285
Copper (mg/L)	0	0	0	0	0	0	0.02	0	0	0.1	0	0	0	0	p=0.476
Hydrocarbon (mg/L)	70	72	0	0	0	70	71	0	0	9.7	9.6	0	0	9.7	P<0.001
Dissolved oxygen (mg/L)	8.46	8.50	8.40	8.3	8.4	8.50	8.47	/	/	7.76	7.60	/	7.55	7.65	P<0.001

Note: S – sample (1–7).

demonstrate that the brine discharge has a higher salinity than the seawater, suggesting minimal dilution before release. The levels of iron and copper remained very low in both seawater and the discharged brine.

Impact of discharge water on the coastline and the marine ecosystem

Field observations at the Bousfer desalination plant's discharge zone raise potential environmental concerns (Figure 2 and Figure 3). A large pipeline lies directly on the shore's surface at the water's edge, which may not be the most aesthetically pleasing solution. More importantly, the presence of foamy and flaky water in various locations suggests possible contamination by chemicals used during desalination, aligning with findings from previous research [Lecomte, 2014].

Reverse osmosis desalination plants typically employ various chemicals, including anti-scalants, coagulants, and cleaning products (surfactants, acids/bases, and chelating agents) [Mehtougui et al., 2013]. The discharge stream also contains wastewater from sand filter backwashing and membrane cleaning processes, along with the concentrated brine solution [Mehtougui et al., 2013]. This aligns with the elevated calcium and TDS levels observed in the analyzed discharge water samples (Table 4). Furthermore, a study by Marques et al. [2023] suggests that anti-scalant chemicals based on polyphosphonates and

Figure 2. Discharge of waste water directly onto the beach

Figure 3. Presence of stagnant flakes and foam in the discharge zone

polymers, commonly used in desalination, can negatively impact the abundance of endosymbiotic algae, potentially disrupting marine ecosystems. These observations and cited research highlight the need for further investigation into the potential environmental consequences of the Bousfer desalination plant's brine discharge practices. Considering alternative discharge methods or exploring ways to minimize chemical use during desalination could be crucial for mitigating any negative environmental impacts.

This study raises concerns about the broader environmental impact of brine discharge beyond the immediate observations at the discharge zone. Chemical pollutants used during desalination, can infiltrate the surrounding soil, potentially causing land and water contamination, disrupting the delicate balance of the marine ecosystem [Câmara et al., 2021; Lecomte, 2014]. The concentrated brine itself can also pose problems. Increased salinity due to brine discharge has been linked to a decline in marine flora, particularly affecting sensitive green algae beds [Capo et al., 2020; Sandoval-Gil et al., 2012].

Furthermore, the visual presence of a large pipeline on the shore (Figure 2) is likely to detract from the aesthetic value of Bousfer beach, potentially impacting tourism and recreational activities. This study also suggests that the water intake process of desalination plants might contribute to the destruction of marine organisms, posing another threat to the coastal ecosystem. These observations highlight the need for a comprehensive environmental impact assessment that goes beyond the desalination plant itself.

Bacteriological analysis

The bacteriological analysis confirms the effectiveness of the reverse osmosis process in eliminating harmful bacteria from seawater. Microbiological testing revealed no traces of *total coliforms*, *Escherichia coli* (*E. coli*), *Enterococci*, or *sulphite-reducing clostridium* in the remineralized drinking water (Table 5). This absence of indicator bacteria aligns with the findings of Zioui et al. [2017] and demonstrates that the desalination process, coupled with disinfection stages, successfully produces water that meets microbiological safety standards for human consumption.

Desalination technology is undergoing a significant shift. Traditionally, thermal processes dominated desalination in Algeria, but advancements in membrane technology, particularly reverse osmosis (RO), have made it a more attractive option due to lower energy consumption and cost [Hamiche et al., 2018]. Research in Algeria is actively exploring and improving membrane technologies like nanofiltration (NF) and reverse osmosis (RO), further reducing desalination costs. A recent pilot study using RO powered by solar panels in Bou Ismaïl (city near Algiers) achieved a promising 32% recovery rate [Tigrine et al., 2023], highlighting the potential of renewable energy sources. However, the environmental impact of brine discharge from desalination plants remains a concern. The concentrated brine can harm marine life unless rigorously treated to meet environmental regulations [Djoher et al., 2020; Omerspahic et al., 2022]. Interestingly, recent studies suggest that RO brine might contain valuable elements and metals [Khan et al., 2021]. Extracting these resources before releasing the brine could offer an economic benefit. Additionally, utilizing diffuser systems for brine discharge could promote faster dilution and minimize salinity impacts on the surrounding environment [Dairi et al., 2023].

While desalination offers a solution for securing freshwater resources, it's crucial to consider its environmental footprint. Efforts to increase water use efficiency and explore wastewater recycling should continue alongside desalination advancements to ensure a sustainable approach to water management.

Table 5. Bacteriological analysis of Drinking Water at Bousfer plant

Parameter	Bousfer plant				DW's standards	
Bacteria	S1	S2	S3	S4	Units	Standard
Total coliforms	0	0	0	0	CFU/100	<10/100 ml
Escherichia coli	0	0	0	0	CFU/100	0/100 ml
Enterococci	0	0	0	0	CFU/100	0/100 ml
Sulphite-reducing Clostridia	0	0	0	0	CFU/100	0/100 ml

Note: DW's standards – Algerian Standard for microbiological quality of drinking water, S – sample (1–4).

CONCLUSION

The building of a desalination plant has numerous environmental effects, some of which are favourable, such as the availability of high-quality water, which is necessary for economic and social growth. Others are unfavourable, such as pollution in the maritime environment, which disrupts and imbalances marine ecosystems, and the change of particular areas from tourist and well-being destinations into industrial zones. The Bousfer mini-station will soon be replaced by the Cap Blanc station, which is now under construction and will have a drinking water capacity of 300,000 m^3/day. The brine, for its part, is intended to be collected by the desalination sectors and reused on the production site or valorized in specific industries like building or glass manufacture. However, the quality standards for salt production, as well as insufficient demand from salt consumers, impede the development of valorization industries.

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