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The Impact of Brine Discharge on Sea Urchins, Case Study of the Bousfer Desalination Plant in West Algeria

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ABSTRACT

This study investigated the potential impact of discharged water from the Bousfer desalination plant in Algeria on the marine environment, with a focus on sea urchins that we found overpopulated in the brine discharge area. To assess the presence of heavy metals, which can pose significant ecological and health risks, water samples were collected from the discharge area and analyzed using atomic absorption spectrometry (AAS). The targeted metals included iron, copper, zinc, nickel, and chromium. The results indicated extremely low concentrations of these metals, with values ranging from ≤ 0.001 to ≤ 0.01 mg/L. This research is the first of its kind at the Bousfer desalination plant and this site was chosen because this station is scheduled to be replaced by a much larger plant. This study suggests that the levels of heavy metals detected in discharged waters are insufficient to pose a direct threat to sea urchins or humans who consume them. However, given the potential for long-term and cumulative effects, further in-depth studies are needed to assess the overall environmental impact of discharged waters on marine ecosystems, including benthic fauna.

Keywords: brine discharge, pollution, sea urchins, desalination, heavy metals, Algeria.

INTRODUCTION

Echinoid sea urchins function as keystone herbivores in marine ecosystems, using their complex feeding apparatus, the Aristotle's lantern, to sculpt the underwater landscape [Nikolaou et al., 2023]. This complex structure houses five robust teeth functioning as a powerful scraping mechanism, allowing them to consume a diverse range of macroalgae and kelp from rocky substrates, reefs, and even man-made structures [Johansson et al., 2010]. Their targeted grazing, notably by species such as the Mediterranean Sea urchin *Paracentrotus lividus*, promotes a heterogeneous algal community by selectively eliminating fast-growing ephemeral algae. This facilitates the establishment of slower-growing, habitat-forming algae that provide essential nursery areas for many fish species. Anthropogenic activities such as predator overfishing or pollution can disrupt sea urchin populations, leading to ecological imbalances. Understanding the multifaceted role of sea urchins is crucial for the conservation and management of healthy and productive marine ecosystems [Wallner-Hahn et al., 2015].

While desalination plants offer a vital solution to freshwater shortages in Mediterranean countries like Algeria, their brine discharges raise concerns about the prevalence of chemicals and their potential impact on marine life, particularly on sea urchins [Lior, 2017]. The desalination process mainly uses two methods: thermal and membrane desalination. Thermal desalination, although less common in the Mediterranean, concentrates seawater through evaporation, leaving behind a brine solution with significantly higher salinity and containing various concentrated contaminants [Pulido-Bosch et al., 2019]. Membrane desalination, the most popular method, uses reverse osmosis membranes to separate fresh water from sea water. However, this process also produces a brine stream enriched with dissolved salts and potentially traces of salt, in addition to chemicals used in pretreatment stages, such as chlorine or antiscalants [El Idrissi et al., 2023]. The prevalence of these chemicals in the Mediterranean sea depends on several factors, including the specific desalination technology used, pretreatment procedures and discharge management practices [Lior, 2017]. Although regulations generally mandate appropriate dilution before discharge, the proximity of discharge points to sensitive ecosystems can lead to localized areas with elevated chemical concentrations. In fact, high levels of copper have been observed near the outfalls of desalination plants due to their use in anti-biofouling treatments [Ternengo et al., 2018].

The dangers these chemicals pose to marine life, including sea urchins, are complex and require further investigation. Increased salinity itself can disrupt osmoregulation in sea urchins, affecting their internal fluid and electrolyte balance [Amri et al., 2017]. Additionally, certain chemicals, such as copper, can be bioaccumulated by sea urchins through ingestion or direct contact, potentially affecting their growth, reproduction, and overall health [Rouchon and Phillips, 2017]. Negative impacts have been noted on sea urchin fertilization and larval development when exposed to high copper concentrations [Bielmyer et al., 2005]. However, specific effects on various sea urchin species and long-term ecological consequences remain areas of ongoing research.

This study represents the initial investigation into the potential environmental impact of the Bousfer desalination plant, Algeria, on the marine ecosystem, particularly focusing on sea urchin populations. This research was prompted by the observed overpopulation of sea urchins in the discharge area, raising concerns about the potential effects of brine discharge. To address these concerns, the concentrations of five heavy metals—iron, copper, zinc, nickel, and chromium—known for their toxicity and bioaccumulation potential in marine organisms, were analyzed in discharge water samples.

Given the planned construction of a larger desalination plant at Cap Blanc, Algeria, understanding the environmental implications of brine discharge is crucial. The results of this study provide a baseline assessment of heavy metal contamination in the discharge water from the Bousfer plant. While the current findings indicate low levels of these metals, insufficient to pose an immediate threat to sea urchins, further comprehensive studies are essential to evaluate the long-term effects on marine ecosystems, including the benthic fauna.

Sea urchins, known for their capacity to bioaccumulate heavy metals and other substances, can act as bioindicators of environmental contamination. Considering the potential toxicity of accumulated substances, ongoing monitoring of both water quality and sea urchin health is crucial. A deeper understanding of the complex interactions between brine discharge, heavy metal accumulation, and marine biodiversity is necessary to inform mitigation strategies and ensure the sustainable operation of future desalination facilities.

MATERIALS AND METHODS

The study area

The Bousfer plant

The Bousfer desalination plant, situated on a 6730 m² site in the commune of Bousfer, Oran Province, Western Algeria, employs reverse osmosis technology to produce 5000 m³ of potable water daily [Mehtougui et al., 2013]. As a critical infrastructure project addressing the region's growing water scarcity, the plant plays a pivotal role in augmenting local water supply and ensuring sustainable water resources management (Figure 1).

The operation of the Bousfer desalination plant

The Bousfer station employs a reverse osmosis, which is a desalination process that leverages pressure to overcome osmotic pressure and purify water. This technique involves forcing a saline solution through a semi-permeable membrane. The membrane selectively permits the passage of water molecules while impeding the movement of ions and larger molecules, such as salts and bacteria. The applied pressure exceeds the osmotic pressure, driving water molecules from the concentrated saline solution to a region of lower solute concentration. The permeate, or purified water, is collected on one side of the membrane, while the concentrated brine is rejected. This process effectively removes dissolved salts and other impurities, producing potable water.

Figure 1. Geographic location and detailed picture of the Bousfer desalination plant (Cap Blanc) in Algeria (Google Earth, 2024)

Sample collection

To assess the efficacy of the desalination process, water samples were collected from the Bousfer desalination plant during March 2023. Specifically, seawater from the intake tank and discharge water from the discharge tank post-reverse osmosis were analyzed for their physicochemical properties. Seven samples were taken at regular intervals for each type of water. The obtained data were averaged, and the characteristics of the discharge water were compared against the international standards used by Algeria to evaluate its suitability for consumption or other intended uses.

Analysis of samples

All samples were analyzed at the control laboratorie of the Bousfer desalination plant and at the laboratory of the SEOR company (The Oran Water and Sanitation Company) as follows:

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:

$$Total\ dissolved\ solid\ matter \left(\frac{mg}{L}\right) = = [(P2 - P1)/V] \times 106 \quad (1)$$

where: $P2$ – weight of the dry residue and the evaporation capsule in mg, $P1$ – weight of the evaporation capsule in mg, V – volume of the sample (100 ml), 106 – 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:

$$Cl- \ (mg/L) = V\ (ml) \times 35.5 \quad (2)$$

where: V – volume of silver nitrate necessary for titration of the solution, 35.5 – reaction factor.

The iron (Fe3+) 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 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 Belkacem, 2014] [Kassouar et al., 2024].

Dosage of heavy metals

In this study we have analysed the concentration various heavy metals also known as elementras metallic (ETM), such as copper (Cu), zinc (Zn), nickel (Ni) and chrome (Cr) using the AA-6200 air acetylene flame atomic absorption spectrophotometry technique (AAS). Flame atomic absorption is a method that allows to measure mainly metals in solution. This method of elementary analysis requires that the measurement be made from an analyte (element to be measured) transformed into the state of free atoms. The sample is brought to a temperature of 2000 to 3000 degrees so that the chemical combinations in which the elements are involved are destroyed.

The calibration ranges were prepared from MERCK type stock solutions (100 ppm) specific to each trace metal element. All samples were diluted to have low analyte contents so that the concentration was proportional to the absorption. All samples assayed by AAS were vacuum filtered through filtration membranes with an equal porosity of 0.45 micrometer. In atomic absorption spectrometry, the absorbance is measured:

$$A = K \times c$$

where: A – absorbance (without unit), c – concentration of the element, k – coefficient specific to each element for the chosen wavelength (λ = 325 nm).

Study in situ

The study area was situated at the outflow point of the Bousfer desalination facility, located in the coastal region of Oran, Algeria. This location was selected due to its potential environmental implications arising from the discharge of highly concentrated saline effluent. The study site was characterized by a shallow, submerged terrain ranging from one to three meters in depth. Divers photographed in pairs using a waterproof digital camera of the GoPro HERO 7 model. Various apps were used in order to correctly measure the meteorological conditions, including wind speed and direction, water currents, wave height, and temperature, for which we used the Windy app. In addition, C-MAP was utilised for the maritime maps.

RESULTS

Evaluation of physicochemical parameters and heavy metals in discharge waters

Our results observed in Figure 2 show an increase in TDS in discharge water following the presence of high concentrations of dissolved suspended matter compared to raw seawater samples. The same observation was noted for chlorides, probably due to the use of sodium hypochlorite (NaClO) during pretreatment. Indeed, the use of antiscalants in desalination causes an increase in these ions in the washing water. Salinity is greater in brine-based discharge water, indicating that it is not diluted before being discharged into the sea (Figure 2). In terms of metal dose, the data demonstrate that there is very little, almost null quantities of heavy metals such as: Iron, Copper, Zinc, Nickel and Chromium in both the salt water or in the discharge water compared to the international standards used by Algeria. These same results were observed for hydrocarbons (Table1) (Figure 2). The results shown in Table 1 are represented in the graph below (Figure 2):

Presence of numerous Sea urchins in the brine discharge zone

Our observations at the brine discharge zone revealed cloudy water with suspended particles (Figure 3), which aligns with the high TDS values obtained in the discharge water (Table 1) (Figure 2). This is likely due to the presence of antiscalants and other biocidal agents used in the desalination industry and present in discharge water containing brines. We also noticed a decline in flora in the contaminated region, indicating a sea urchin overpopulation (Figure 4).

DISCUSSION

Faced with an increasing freshwater deficit, desalination facilities have emerged as a critical option for Mediterranean countries, particularly Algeria. However, their brine discharges raise worries about possible environmental contamination. Sea urchins, which are classed biologically as Echinoidea, appear to be promising

Table 1. Physico-chemical parameters of seawater and discharge water (average of 7 samples)

Parametres	Seawater	Discharge water	Limit values
Salinity mg/l	37386.01	41314.31	35500
TDS mg/l	39142.23	47134.42	27750
Chloride mg/l	9428.5	15479.84	21431
Iron mg/l	0.006	0.001	3
Copper mg/l	0.003	0.01	0.5
Zinc mg/l	0	0	3
Nickel mg/l	0.03	0	0.5
Chrome mg/l	0.001	0	0.5
Hydrocarbon mg/l	40.41	4.14	10

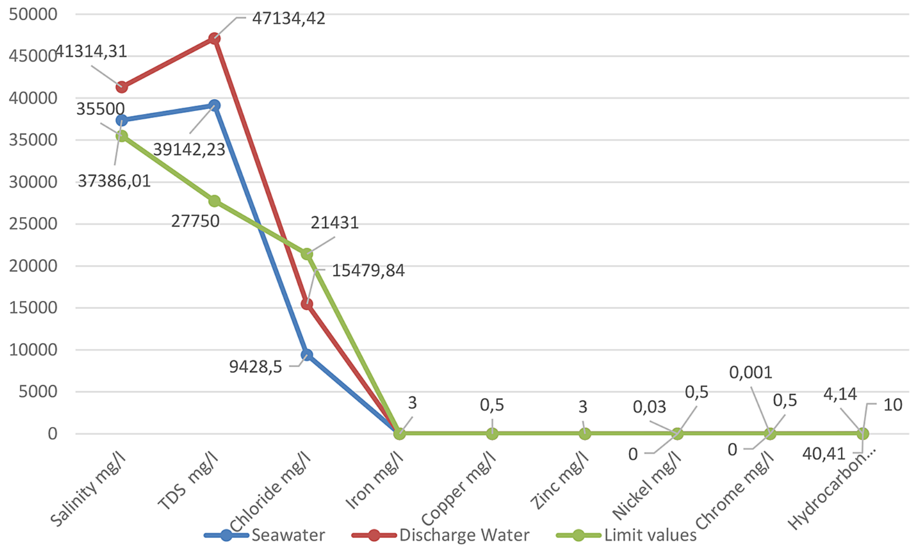

Figure 2. Comparison between the physico-chemical parameters of seawater and discharge water (average of 7 samples)

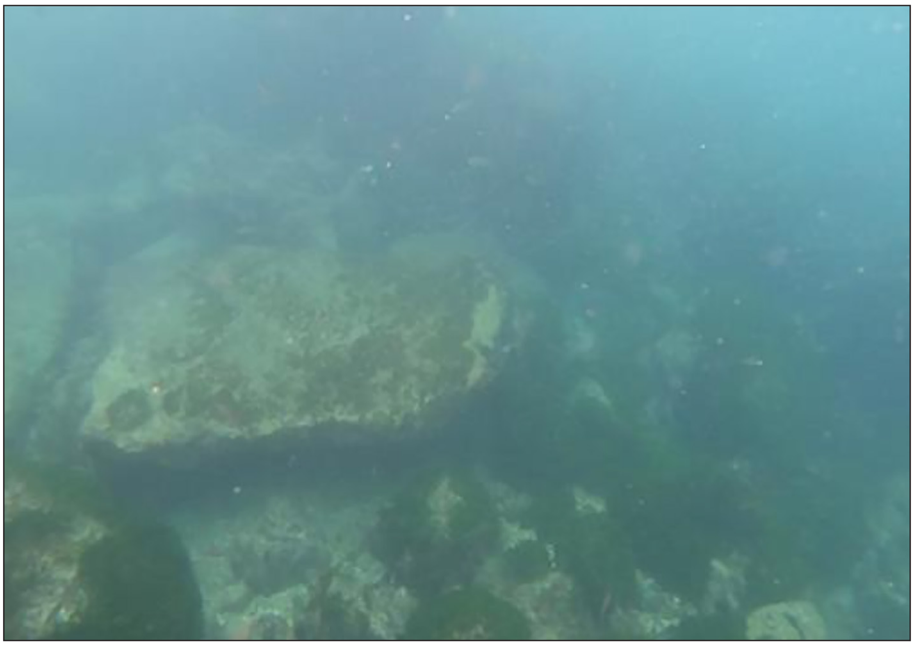

Figure 3. Turbid water in the brine discharge zone of the Bousfer plant

bioindicators for monitoring pollution levels in these places. Their particular biological properties make them ideal for this role [Parra-Luna et al., 2020]. Indeed, sea urchins have a relatively sedentary lifestyle with limited mobility. This characteristic confines them close to the desalination plant's discharge point, giving a localised picture of environmental conditions [El Idrissi et al., 2023]. Our on-site observations support these findings (Figure 4). Unlike mobile organisms that can migrate far from contaminated places, sea urchins are a constant indication of environmental quality [Câmara et al., 2021].

Their dietary habits increase their significance as bioindicators. As omnivores, they graze on algae and debris, effectively serving as ecosystem integrators [Nikolaou et al., 2023]. These findings support our observations (Figure 4a). Sea urchins can bioaccumulate pollutants from their food sources, particularly those that may be higher near brine discharge regions. This bioaccumulation capability makes them especially valuable for identifying chronic, low-level contamination

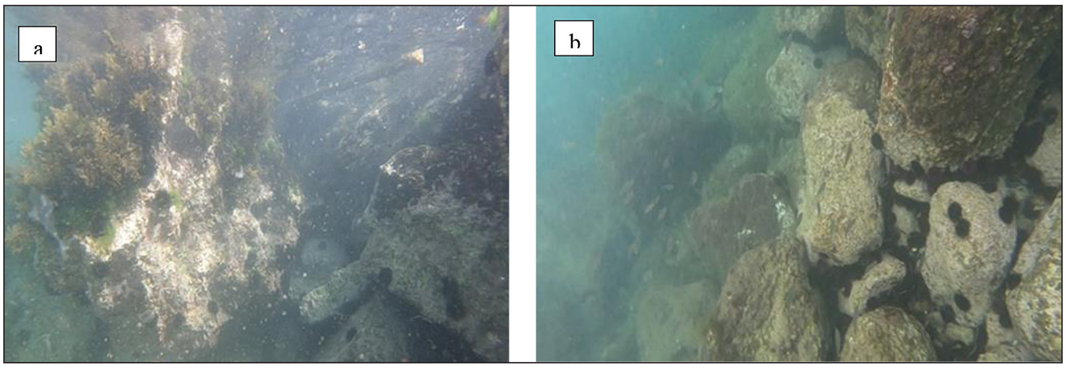

Figure 4. Decrease in benthic flora and appearance of numerous sea urchins in the brine discharge zone at the Bousfer plant

that may not be easily detected by traditional water quality monitoring [Morroni et al., 2023].

Previous studies on Paracentrotus lividus have yielded varying results concerning contaminant accumulation. While investigations conducted on the northwestern Portuguese coast identified contaminants within sea urchin reproductive tissues, the levels detected were deemed insufficient to pose a human health risk [Parra-Luna et al., 2020]. Conversely, a study carried out near the Canari asbestos mine in Corsica reported no adverse effects on Paracentrotus lividus despite trace element pollution from mining waste [El Idrissi et al., 2023]. Our analysis of heavy metals such as iron, copper, zinc, nickel and chromium concentrations in brine discharge water revealed no significant environmental presence of these metals.

Using sea urchins as bioindicators can provide vital information on the possible ecological effect of brine discharges from desalination facilities into the Mediterranean Sea. This method can help to reduce the environmental concerns associated with brine discharges and encourage sustainable water management practices that balance human needs with marine ecosystem health.

The potential health risks associated with consuming sea urchins contaminated with pollutants remains an evolving area of scientific research. Although evidence indicates that the likelihood of harm, its particular implications and level of risk warrant additional exploration.

One of the primary problems is the bioaccumulation of contaminants in sea urchins. Sea urchins can swallow contaminants such as heavy metals, persistent organic pollutants (POPs), and microplastics when feeding on algae and debris [Albarano et al., 2021]. Sea urchins, which are frequently filter feeders, can concentrate these contaminants to levels greater than those seen in the surrounding ecosystem, a phenomenon known as biomagnification. This might endanger human health if infected sea urchins are ingested [Savoca et al., 2021].

The potential health effects of ingesting contaminated sea urchins are determined by the individual contaminant and its concentration. Heavy metals like mercury and lead can accumulate in the body, causing brain impairment, developmental issues, and renal difficulties. POPs including PCBs and DDT can affect hormone function and have been associated to a variety of malignancies [Albarano et al., 2021]. Microplastics are a developing issue, with possible implications for gut health and inflammation, however research is still in its early phases [Stabili and Pagliara, 2015] [Wen-xiong, 2023].

However, it is critical to recognise the limitations of present understanding. Although studies have shown that contaminants can bioaccumulate in sea urchins [Bouchoucha et al., 2016] [Parra-Luna et al., 2020] [Rouchon and Phillips, 2017], the translation into threats to human health requires more in-depth investigation. Potential dangers are influenced by factors such as the types of pollutants used, their quantities in ingested sea urchins, and individual metabolic variances.

CONCLUSION

This study focused on assessing the potential impact of brine discharge from the Bousfer desalination plant, Algeria, on sea urchin populations inhabiting the discharge area. Given the known toxicity of heavy metals and the bioaccumulation capacity of sea urchins, the study concentrated on analyzing the levels of iron, copper, zinc, nickel, and chromium in the discharge waters. Our findings indicate extremely low concentrations of these metals, suggesting a negligible risk posed by the discharge water to both sea urchins and human consumers. This is particularly reassuring considering the upcoming replacement of the Bousfer plant with a larger desalination facility. The Algerian government's commitment to preserving marine ecosystems and benthic fauna through various regulatory measures is commendable.

However, given the complex nature of marine ecosystems and the potential for long-term effects, further in-depth research is warranted. The bioaccumulation capacity of sea urchins highlights the need for continued monitoring of both water quality and sea urchin health. By expanding the scope of investigation to include other potential contaminants and a wider range of marine organisms, a more comprehensive understanding of the environmental implications of brine discharge can be achieved.

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