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Potential Impacts of Discharges from Seawater Reverse Osmosis on Algeria Marine Environment

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Abstract: Desalination processes have environmental impacts. The brine water discharge has an impact on marine ecosystem. This is mostly due to the highly saline brine that is discharged into the sea, which may be increased by temperature, contain residual chemicals from the pretreatment process, heavy metals from corrosion or intermittently used cleaning agents. The effluent from desalination plants is a multi-component waste, with multiple effects on water, sediment and marine organisms. Therefore, it affects the quality of the resource which it depends on. In this study, selected water quality parameters in the seawater and the presence of heavy metals of concern in the sediments and algae were monitored to investigate the impacts of the discharges by seawater desalination plants using reverse osmosis on the receiving marine environment. In light of the results obtained, the analyzed water has a physicochemical quality more or less adequate, moreover, chemical analyzes in seaweed and sediments show relatively low levels of heavy metals.

Key words: Desalination, brine, physicochemical, algae, sediment, contamination.

1. Introduction

Water is an abundant resource that covers about three-quarters of the surface of the earth, yet only 2.5% is drinkable. Water availability is declining and there is no spatial or temporal uniformity [1]. The problems of scarcity affect a third of the world population and these problems will increase in the future [2, 3]. Desalination is being used by many countries to alleviate the shortage of water and enable economic, social and environmental development, and is ultimately a tool to preserve natural resources and protect the environment [4-6]. Commercial desalination technologies can be divided into two main categories: thermal distillation (Multiple-Stage Flash (MSF) and Multiple-Effect Distillation (MED)) and membrane separation (Reverse Osmosis (RO)) [5, 7]. Thermal processes were mainly used in large and medium sized plants, while reverse osmosis was employed in smaller installations. However, improvements in membranes in recent years have enabled the use of reverse osmosis in large installations [1, 5, 8]. Thermal processes are currently used in the Gulf and North Africa, which have considerable energy resources. While, reverse osmosis is used in the majority of developed countries and those nations with few energy resources, because it is more efficient in terms of energy and cost [1, 8-11]. Desalination is a process that can generate unintended impacts and damage coastal areas, so to avoid unsustainable and poorly planned developments, planning policies must be integrated into the management of water resources and coastal resources [8, 12]. Environmental impacts are now addressed in the literature but mostly as a theoretical analysis that include entrainment and impingement of organisms at the intake. And at the outfall, it includes increased salinity and stratification, reduced vertical mixing, decrease in oxygen concentration, increased turbidity, euthrophication, decreased or increased production,

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toxicity, mitigation techniques [13-15]. A large proportion of the published work is descriptive and provides little quantitative data. The number of published articles with actual measurements of effects in situ or in lab experiments is small and limited in scope [16]. Most of the publications emphasize the effects of salinity on the benthic communities and those are site and organism specific [17-20].

The main objective of the present study is to show the effects of the discharges brine water from Bou Ismail's (Algeria) desalination plant on seawater quality and measuring the concentration of heavy metals in an accumulator bio-algae and sediment in the turn of the rejection of the station.

2. Material and Methods

2.1 Studied Area

Bou Ismail desalination plant is located at the coast of the bay of Bou Ismail (from west to east Chenoua in Sidi Fredj), north of Algeria (Fig. 1). It started to operate in 2004. It is designed for a capacity of 5,000 m^3/d. This installation of "reverse osmosis" kind consists of the sections in industrial process:

(1) A seawater outlet;
(2) Pretreatment station;
(3) The reverse osmosis unit;
(4) A packing station of drinking water;
(5) A dosing station;
(6) An analysis station;
(7) Cleaning station membrane modules.

The production processes result in liquid discharges a flow of 416 m^3/hour, which is then rejected by pipes to the sea.

The plant at present is non-functional due to technical problems, but in future, may decrease the efficiency of units due to pollution of feeding water intake source.

2.2 Analysis and Experimental Work

The experimental work is done over 3 missions (April to June). The collected samples have been testing for chemical analysis to know the level of

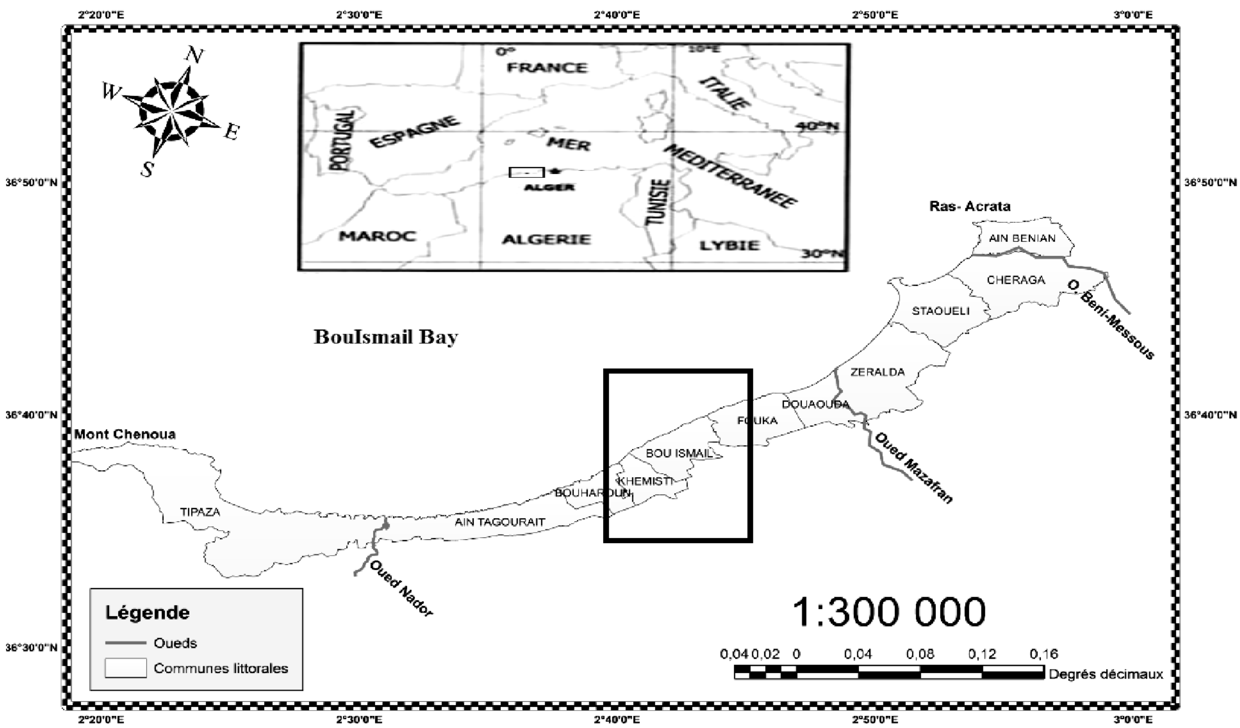

Fig. 1 Location of desalination plant of Bou Ismail.

maximum concentration of heavy metals in brown algae (*Cystoseira compressa*) and sediments, the elements (Cd, Pb, Cr and Hg) were analyzed. Physico-chemical parameters analyzed have commonly been used as important markers of continental influence, particularly in cases involving mixtures of seawater with inland waters.

The physic-chemical species used in the present study involved the in situ measurement and analysis of temperature, pH, salinity and dissolved oxygen (these parameters were measured by a multi-parameter and nutrient salts, nitrites, nitrates, ammonia nitrogen and phosphorus) as previously described elsewhere [21, 22]. The water samples were collected at 50 cm below the surface using plastic bottles, previously rinsed with water. They were then stored at 4 °C during transport to the laboratory.

Cystoseira compressa has been chosen because of their abundance near the desalination plant rejection and also their power to accumulated heavy metals.

A single sampling of sediments (300 g) was collected next to the algae scraping the first cm surface with a spoon in stainless steel. Sediment samples are collected in polyethylene pots, and were carefully tacked to avoid contamination. They were kept on board (pre-freezing) in the laboratory and submitted to the treatment.

Specimens of brown algae *Cystoseira compressa* were sampled on a seasonal basis throughout the period of the study following a sampling protocol described [23]. The collected algal samples were cleared of their epiphytes and debris adhering to their fronds, washed up on the sea water and then placed in plastic bags. Upon arrival at the laboratory, the algae were rinsed with double distilled water, dried at 70 °C for 48 h, and then ground to a fine powder. The powder was then used for mineralization assays.

Heavy metals assayed by atomic absorption spectrometer performed by a Perkin Elmer Analyst 700 atomic absorption spectrometer equipped with a flame, furnace and cold vapor system connected to the Flow Injection for Atomic Spectroscopy (FIAS) system, a mechanism that allowed for the analysis of the evaporation reaction of the mixture of mercury, HCl, Sn (II) Cl_2 and the sample. The carrier gas was argon—an inert gas that does not react with the test solutions.

3. Results and Discussion

3.1 Variation of Physicochemical Parameters of Receiving Seawater

Table 1 summarizes the water quality information of receiving seawaters including the temperature, pH, dissolved oxygene, salinity and nutrient (phosphorus, ammonium, nitrite and nitrate).

Temperature values recorded during the study period were within the limits of seasonal values. This shows that the desalination process used (reverse osmosis) in this station has no effect on the temperature of the brine and the receiving medium. This was confirmed by a study [24]. And an increase in temperature between the seawater and brine is relatively small: a rise of 0.65 °C was found in the waters of releases factory Fujairah United Arab Emirates.

Table 1 Water quality information of receiving seawaters from the monitoring of desalination plant.

Paramater	P1 (march)	P2 (May)	P3 (June)
Temperature (°C)	16.3 ± 0.01	18.5 ± 0.2	21.78 ± 0.09
pH	6.52 ± 0.0166	6.43 ± 0.01	6.39 ± 0.03
Dissoleved oxygen (mg·L^{-1})	3.37 ± 0.04	2.94 + 0.04 – 0.07	2.35 ± 0.01
Salinity	43.6 + 0.06 – 0.05	42.93 + 0.016 – 0.013	42.96 + 0.0163 – 0.023
Ortophosphate (mg·L^{-1})	0.54 ± 0.01	1.22 ± 0.01	1.94 ± 0.01
Ammoniacal nitrogen (mg·L^{-1})	0.037 ± 0.001	0.05 ± 0.001	0.068 ± 0.001
Nitrate (mg·L^{-1})	1.43 ± 0.01	0.50 ± 0.001	5.57 ± 0.01
Nitrite (mg·L^{-1})	0.651 ± 0.002	0.414 ± 0.003	0.267 ± 0.004

The pH of seawater analysis shows a slight stability of acidity (6.36-6.52) on all of the different samples. The pH values are relatively homogeneous, they are close to the pH values found naturally in Algerian waters bounded from 6 to 8.5. And the result found is probably due to chemical release of the station, such as sulfuric acid H_2SO_4 and chloride acid (HCl), which used to adjusted pH [26]. As a general rule, at low pH, when surface sites are protonated, the sorption of cationic metals decreases, and hence, trace metals mobility increases. The converse occurs at high pH, which results in low metal solubility and greater sorption. According to Lattemann, S. et al. [27], fish are capable of avoiding acidic discharge plumes from desalination plant, less mobile organisms such as star fish, mollusks, horse fish, etc. will be directly affected by acid blow-down.

The values of salinity sea water are relatively high (42, 93 to 43.6 Pratical Salinity Unit (PSU)) and are superior to those of the Mediterranean (37.8 and 39.3 PSU). This increase in the salinity is due mainly to the rejected brine in sea water which is 1.2-3 times more concentrated than in salt sea water [27]. These results are similar to those found by Fernandez-Torquemada, Y. et al. [17] in the Alicante seawater desalination plant (SE Spain) and by the work of Malfeito, J. J. et al. [29] in the fantana of Javea desalination station channel in Spain. It forms a feather in highly saline sea bottom or she reaches a concentration of 42 g/L. It is due to the difference in density between the sea and the brine. It extends a distance of 120 cm. So, it causes continuous damage to the aquatic fauna and flora, especially in the coastal marine inhabitants. According to the work of Jacqueline Dupavillon, L. et al. [30], the brine concentration of 50 g/L have an inhibitory effect on the growth and development of apama Sepia and the microscopic bacteria or fungi pathogen.

During the three samples, the concentration of low dissolved oxygen (2.35-3.37 mg/L) is low. These values are probably related to the increased salinity marked at study site because the dissolution of O_2 in sea water depends on the temperature and salinity. This was shown by the study of Dawood, M., and Al Mulla, A. [26]. It can also be explained by the presence of polluting activities (microbial decomposition of chemicals used during treatment).

Significant enrichment in phosphorus was observed all samples showed levels of above 0.5 mg/L, which was an indication of pollution. High levels of pollution have probably attributed from the degradation of organic matter or sodium tripolyphosphate (used for the preparation of a chemical cleaning solution from the desalination plant), or hexametaphosphate (antiscalant product) to avoid pie in pipes and membranes.

Variations of ammoniacal nitrogen contents are characterized by increased along the three samples. But these values are lower than the recommended value (0.1 mg /L). These low values may be explained by a mixing of the water and the preferred use of aquatic species of ammoniacal nitrogen (NH^+), which is the most reduced form and the most advantageous point of view of energy. The values stored nitrates are quite large, along the three samples. The high nitrate concentration is due to its regeneration by microorganisms and that the degradation of organic matter or the introduction into the marine environment of organic matter are highly oxidized and degraded via brine. The values recorded for nitrites were lower than the standard value set at 3 mg/L and a water containing nitrite is considered suspect water because they are only one term passage between the nitrates and ammonium forms. The concentration of ammonium and nitrite are not influenced by the discharges.

3.2 Sediment Metal Content

The changes recorded for trace metals (Cd, Pb, Cr and Hg) in sediments are presented in Table 2. Sediments are considered to be “sinks” of contaminants where they can reside for long periods of time [30, 31]. And heavy metals in sediment are of concern because

Table 2 Concentration of heavy metal in sediment and algae.

	Sediment	Algae (March)	Algae (May)	Algae (June)
Chromium (mg/kg)	6	1.4	1.9	0.3
Lead (mg/kg)	7.05	5.1	5.1	0.3
Cadmium (mg/kg)	0.5	0.1	0.1	0.1

of the long-term problems caused by the bioaccumulation of metals by marine organisms [32].

Cadmium: sediments in uncontaminated inshore areas contain < 0.5 ppm Cd [33]. Suspected contamination from oil activities would show around 10 ppm Cd, so, sewage and industrial wastes (such as the New Bedford Harbour level) would be expected to contain 66-1,000 ppm Cd [33, 34]. From the data presented in Table 2, the sediments are uncontaminated.

Lead: uncontaminated sediments might be expected to contain < 6 ppm Pb [33]. Estuary sediment of polluted rivers typically shows < 10-50 ppm Pb and up to 850 ppm [34]. On this basis, the sediment of station is uncontaminated.

Chromium: the level of Cr in these sediments is low, so the sediment of station is uncontaminated.

Concentrations of heavy metals in sediments desalination discharge near Bou Ismail reverse osmosis are inferior to those found by Sadiq, M. [36]. This study found high concentrations of the measured metals in sediment samples at the immediate vicinity of the outfall of the desalination plant. However, these elevated levels decreased progressively away from the outfall, suggesting a localized pollution in that area. In addition, it has been shown by Dawood, M., and Al Mulla, A. [26]. The brine rejected from reverse osmosis plants contains only traces of heavy metals, so the contamination of the environment is generally insignificant and therefore ineffective for wildlife and local flora.

3.3 Concentrations of Heavy Metals in the Algae

Macroalgae are one of the most appropriate bodies for monitoring pollution by heavy metals in coastal areas [36-41]. They are preferable to the measurement of metal levels in water or sediment [41]. Brown algae were frequently used for coastal surveillance waters [36]. *Cystoseira compressa* is widely used as a biological indicator of the metal contamination in many parts of the world.

Following the results, the concentration of metals analyzed seems different in seaweed collected around desalination discharge. The highest concentrations are those of lead tracking chromium, cadmium and mercury, and it is observed along the three samples. This shows that the accumulation of metals occurs preferentially in algae compared to the available form of metals, with the size of organisms, ecology and morphology, the immersion period and exposure of algae [42].

This is clearly shown by the analysis of variance to one factor (ANOVA) with Excel, which was performed for the comparison of trace metal concentrations in seaweed *Cystoseira compressa* for the three periods of samples. The result of this test showed that calculated F ($F = 30.80$) is greater than F of the table of Fisher-Senedecor 0.05 ($F = 3.05$), this implies that the null hypothesis (H_0) is rejected. So there is a significant difference between the concentrations of heavy metals in the three periods of development of the algae with a 95% safety levels.

Pb concentrations along the levies are high. The usual concentration of Pb in the algae is between 2 ug/g and 3 ug/g [44]. According to Sivalingam, P. M., and Lozano, G. et al. [41, 45], the values excedant 10 ug/g are assigned only to species of algae contaminated areas. In this study, the found concentrations are lower at 10 ug/g in the species that indicate a low level of pollution in the area. During the third sample, it is noted accumulation rate of decrease of the lead with respect to the first two stages, which shows that the accumulation depends on the age may be related to metabolic processes.

The Cd content is virtually unchanged for all samples, and the three stages of development of the algae, these levels are lower expected values for a contaminated area [41]. Measured the concentrations of Cd in seven species of brown algae in coastal areas of the Canary Islands and that they regarded any sample containing more than 2 ug/g cadmium as a polluted algae.

The concentrations of chromium analyzed in seaweed along the samples (0.3-1.9 mg/kg) are lower. And it's noted that the accumulation is more intense when the algae is juvenile compared to adult stage.

4. Conclusion

Marine ecosystem and biodiversity are threatened by brine discharged from Bou Ismail desalination plant.

Results indicated that the measured physicochemical parameters have a stress that can disrupt the metabolism and physiological activity of the flora and fauna of the site.

Regarding metals, they have demonstrated a low meter metallic pollution of sediment and algae.

It is important to note that this study attempts to assess the possibility of an anthropogenic effect as well as potential accumulation of heavy metals among various types of environmental pollutants in the outfall areas of desalination plants rather than an affirmative conclusion regarding their adverse environmental impacts. This information is likely to be more important, while the discharge from the reverse osmosis technology is typically considered less environmentally detrimental by containing low concentrations of various pollutants. In addition, the findings from this research provided insight regarding the difficulty associated with current regulations that typically predict the influences or assess the impacts with short-term environmental monitoring. In this case, insufficiently-long data collection makes it possible that the real environmental impacts caused by desalination processes may go underestimated. Further investigations by continuous and long-term monitoring of these heavy metals as well as other contaminants are necessary, and will provide additional information to verify the environmental impacts of brine discharges from seawater desalination using reverse osmosis on the receiving marine environment and ecosystem.

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