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EVALUATION OF THE IMPACT OF THE DESALINATION PLANT ON THE MARINE ENVIRONMENT: CASE STUDY IN ALGERIA.

ÉVALUATION DE L'IMPACT DE L'USINE DE DESSALEMENT SUR LE MILIEU MARIN: ETUDE DE CAS EN ALGERIE.

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ABSTRACT

This work focuses on Environmental impacts associated with concentrated brine rejection arising from seawater desalination plants in Algeria. We present a case study on the environmental impacts of BouIsmail/MSF seawater desalination plant. These impacts are 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.

We performed the measurement of seawater quality the concentration of heavy metals in an accumulator bio-algae and sediment in the turn of the rejection of the station. And the study of the phytoplankton density at different discharge distance. Global results show no effect while there is a local impact due to the relatively small size of the resort of plant.

Keywords: Seawater, Desalination, Quality, Sediment, Algae, Phytoplankton

RESUME

Ce travail se concentre sur les impacts environnementaux associés au rejet de la saumure provenant des usines de dessalement de l'eau de mer en Algérie. Nous présentons une étude de cas sur les impacts environnementaux de l'usine de dessalement d'eau de mer Bou Ismail. Ces impacts sont principalement dus à la saumure très salée qui est déversée dans la mer, contient des produits chimiques résiduels du processus de prétraitement, des métaux lourds qui sont les produits de la corrosion du circuit.

Nous avons effectué la mesure des paramètres physicochimique de l'eau de mer et la concentration des métaux lourds dans une algue bio accumulatrice et de sédiments à proximité des rejets de la station. Et l'étude de la densité du phytoplancton à différentes distances de décharge. Les résultats globaux ne montrent aucun effet alors qu'il y a un impact local en raison de la taille relativement petite de la station.

Mots-clés : Eau de mer, dessalement, qualité, sédiments, algues, phytoplancton

INTRODUCTION

Over the past several decades, the rapid growth in human populations and industrial activities continued to place ever-increasing pressure upon the demand for clean water. As a result, many nations are turning to seawater desalination to complement other sources of water supply). Commercial desalination technologies can be divided into two main categories: thermal distillation (multi-stage flash or MSF, and multiple-effect distillation or MED); and membrane separation (reverse osmosis or RO) (Mezher et al.,2011 ; Tsiourtis., 2001).

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 (Karagiannis., 2008 ; Tsiourtis.,2001 ; Lattemann.,2008). 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 (Karagiannis., 2008; Lattemann.,2008) and those nations with few energy resources (Tsiourtis.,2001 ; Al-Agha.,2008) because it is more efficient in terms of energy and cost(Karagiannis., 2008; Einav and al.,2002).

Algeria experience in desalination started during the sixties with the building of multi-stage flash distillation (MSF) and mechanical vapor compression (MVC) plants in order to supply with water the growing oil and steel industries (Bravo.,2004). Forty four (44) MSF seawater desalination plants totalizing a capacity of 111.000 m^3/day are supplying the petrochemical process industry and power generation plants (e.g. most of the Algerian steam power plants are fed with distillate water from small scale MSF desalination plants).

Desalination is nevertheless a high energy consumption process contributing to GHGs emissions and a potential threat to the environment by inducing damage to the marine environment. The research devoted to the assessment of impacts of desalination on the marine ecosystems are so far limited (Latteman., 2003 ; Tamim.,2005; Santana.,2005). More than 15,000 desalination plants around the world lead to a substantial production of brine from brackish and seawater desalination, while a half of intake massflowrateis rejected. The discarded brine has an impact on marine environment as its concentration is about twice the intake seawater and include Pre- and post-treatment chemicals. While energy recovery through pressure exchangers or Pelton turbines is widely used, production of salt and additional water from the rejected brine is a part of the solution but is economically not often feasible.

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, the study of the phytoplankton density at different discharge distance and measuring the concentration of heavy metals in an accumulator bio-algae and sediment in the turn of the rejection of the station.

MATERIALS AND METHODS

The BouIsmail MSF desalination plant is located 50 km West of Algiers (Algeria), on the Mediterranean coast. Exactly on the Bay of BouIsmaïl (from West to East Chenoua in Sidi Fredj) north of Algeria (Fig. 1). It started to operate in 2004.

The nominal distilled water production is 5000 m^3 /day. The plant consists 6 subsystems:

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 m3/ hour, which is then rejected by pipes to the sea.

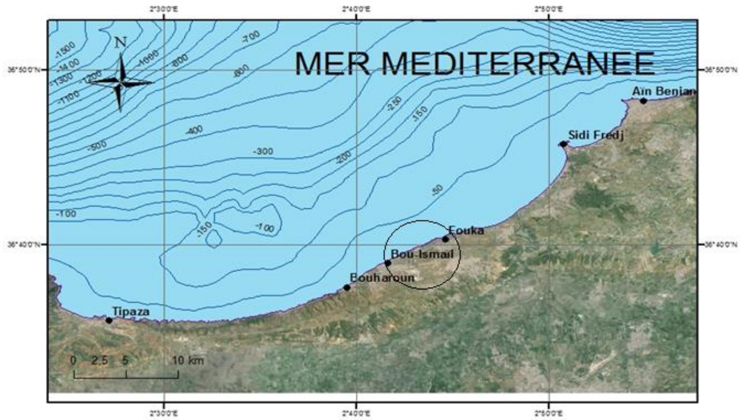

Figure 1: Location of desalination plant of Bou Ismail

ANALYSIS AND EXPERIMENTAL WORK

The experimental work done over 3 missions (April to June). The collected samples have been testing for chemical analysis to know the level of maximum concentration of heavy metals in brown algae (Cystoseira compressa) and sediments, the following elements was analyzed (Cd, Pb, Cr)

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, dissolved oxygen (these parameters were measured by a multi-parameter, and nutrient salts (nitrites, nitrates, ammonia nitrogen, and phosphorus) as previously described elsewhere (Boukhalfa and al., 2006 ; Rodier., 1996). 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.

To study phytoplankton sampling was performed on the surface in the polyethylene terephthalate bottles of 500ml. The fixing of the samples was performed immediately after sampling. The fixer used is lugol. The samples are kept in the dark the samples were carried out at different discharge distance (5m, 10m, and 40m). The couting of the phytoplankton has been done with inverted microscope.

(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 (Aminot and Chaussepied., 1983). 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 ISAF, a mechanism that allowed for the analysis of the evaporation reaction of the mixture of mercury, HCl, Sn (II) Cl2, and the sample. The carrier gas was argon, an inert gas that does not react with the test solutions.

RESULTS AND DISCUSSION

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 therefore on the receiving medium. This was confirmed by the study of Dweiri and Badran, 2002 .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 H2SO4 and chloride acid (HCL) (Dawood and Al Mulla, 2012) used to adjusted pH. 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., 2003), 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) 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 to 3 times more concentrated than in salt sea water (Vanhems., 1992). These results are similar to those found by Fernandez-Torquemada.Y and al., 2005 in the Alicante seawater desalination plant (SE Spain) and by the work of (JJMalfeito and al., 2005) in the fantana of Javea desalination station channel in Spain Its forms a feather in highly saline sea bottom or she reaches a concentration 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 work (Jacqueline Dupavillon L and al., 2009) the brine concentration of 50 g/l have an inhibitory effect on the growth and development of apama Sepia, and on the microscopic bacteria, or fungi pathogen.

During the three samples, we recorded low dissolved oxygen (2.35 to 3.37 mg/l). These values are probably related to the increased salinity marked at study site because the dissolution of O2 in sea water depends on the temperature and salinity. This was shown by the study of (Dawood., 2012). It can be 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 $mg.l^{-1}$, 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 highly oxidized and degraded via brine. The values recorded for nitrites were lower than the standard value set at 3 mg l^{-1} and a water containing nitrite is considered suspect water because they are only one term passage between the nitrates and ammonium forms (Faurie et al., 2003). The concentration of ammonium and nitrite are not influenced by the discharges.

The quantitative study of the phytoplankton cells

The quantitative study of the phytoplankton cells count gave a density total cell which varies from one station to another, It is noted that this density varies between a minimum value of 56 Cell./l at the station which is to rejection of 5m and a maximum of 416 Cell./l at the located 30m discharge station and the other station brand an average value of 180 Cell./l in total density. Indeed, the low marked cell concentrations find their explanation of the fact that rejection is considered highly charged with chlorine which causes a partial reduction light penetration. Ferric chloride used in reverse osmosis stations increases the turbidity of brine in output that can cause discomfort to the animals and flora. (Lattemann Höpner S & T, 2008). It can also be explained by increasing salinity.

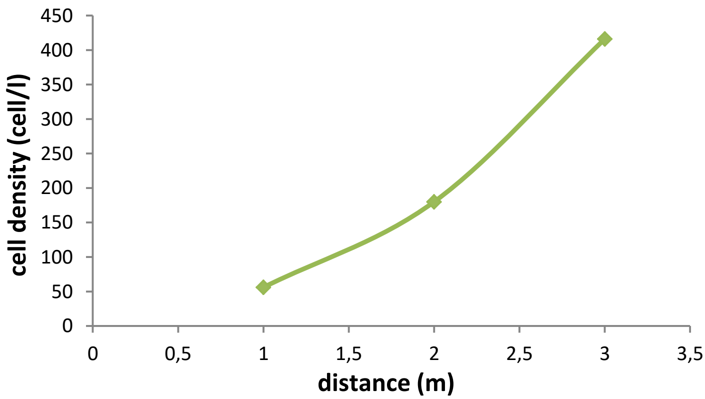

Figure 2: variation of the total cell population densities Phytoplankton relative to the discharge point

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 (NOAA,1991; Schiff,2000) and heavy metals in sediment are of concern because of the long-term problems caused by the bioaccumulation of metals by marine organisms (Povlesen,2003).

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

Cadmium

Sediments in uncontaminated inshore areas contain < 0.5 ppm Cd (Langston, 1990). Suspected contamination from oil activities would show around 10 ppm Cd, whilst it is a component of waste waters, anti-corrosion paints and Ni-Cd batteries and highly contaminated sites affected by ore mining, sewage and industrial wastes (such as the New Bedford Harbour level) would be expected to contain 66 to 1,000 ppm Cd (Langston., 1990; GESAMP., 1985). From the data presented here, the sediments are uncontaminated.

Lead

Uncontaminated sediments might be expected to contain <6 ppm Pb (Langston., 1990). Estuary sediment of polluted rivers typically show <10–50 ppm Pb and up to 850 ppm (GESAMP., 1985). 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.

Concentration of heavy metals in sediments desalination discharge near Bou Ismail reverse osmosis is inferior to those found by (Sadiq et al, 2002). 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 and Al Mulla, 2012) as brine releases from reverse osmosis plants containing only traces of heavy metals, contamination of the induced medium is generally insignificant and therefore ineffective for wildlife and local flora.

Concentrations of heavy metals in the Algae

Macroalgae are one of the most appropriate bodies for monitoring pollution by heavy metals in coastal areas (Amado et al., 1999; Giusti, 2001; and Sawidis et al., 2001; Conti and Cecchetti., 2003; Lozano et al., 2003; Topcuoglo et al., 2003), they are preferable to the measurement of metal levels in water or sediment (Topcuoglu and al., 2003), brown algae were frequently used for coastal surveillance waters (Amado et al., 1999). 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 (Benbrahim et al., 1998; Zeroual, 2003).

This is clearly shown by the analysis of variance to one factor (ANOVA) with Excel, 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 (F = 3.05), this implies that the null hypothesis (H0) is rejected. We can therefore conclude that 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 and 3 ug g-1 (Prosi., 1986), According (Sivalingam., 1978, Lozano et al., 2003), the values excédant 10 ug g-1 are assigned only to species of algae contaminated areas. In this study, the found concentrations are lower at 10 ug g-1 in the species that indicate a low level of pollution in the area. During the third sample 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 it 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, (Lozano et al., 2003) 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-1 cadmium as a polluted algae.

The concentrations of chromium analyzed in seaweed along the samples (0.3 to 1.9 mg/kg) are lower with those identified by (Dento et al., 2006) and (Al-Masri and al., 2003). We also note that the accumulation is more intense when the algae is juvenile compared to adult stage.

CONCLUSION

Our work had aimed the evaluation of the impact of discharges stations desalination on the aquatic environment and to prevent the effects caused by these effluents to ensure the preservation of the environment and biodiversity.

To this end, our study is based on physico-chemical, biological and bioaccumulation of heavy metals essential for highlighting the rejection of dispersion (brine) of the desalination plant and its consequences on the marine environment.

The results of physic-chemical, biological (phytoplanckton) and the parameters of pollution obtained in our various analyzes have shown that the brines products by desalination technologies (reverse osmosis) have a high salt content resulting from the concentration of desalinated sea water (salinity from 42.2 ‰ higher than that of water36.55 ‰ sea).

Therefore, these effects lead to a disruption of the local aquatic life. This phenomenon is attenuated quickly as and as one moves away from the discharge point. 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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