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Chemical elements of brine discharge from operational Tajoura reverse osmosis desalination plant

Bashir Brika*, Abdul Aziz Omran, Obiyda Dia Addien

Water Desalination Research Section, Water Desalination Department, Tajoura Nuclear Research Center (TNRC), Tripoli, Libya, Tel. +218 92 5411305; Fax: +218 21 3614142; emails: bashirforlibya@gmail.com (B. Brika), azize2515@yahoo.com (A.A. Omran), hitweich@yahoo.com (O. Dia Addien)

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ABSTRACT

Despite the fact that desalination is an important technology for providing desalted water, it has some disadvantages that have not been taken seriously into consideration. Such technology can have undesirable effect on the environment. Environmental related impact could occur from the early days of plant construction and, subsequently, when the plant is in operation. Tajoura reverse osmosis desalination plant is the largest desalination plant of its kind in Libya. It has been under operation for nearly three decades without serious consideration of its impact on the environment. This paper is the first attempt in that direction. The main objective of this study is to measure the chemical components of brine concentrate discharged from Tajoura plant, and to highlight their impact on the environment. This study was conducted in the Water Desalination Department in Tajoura Nuclear Research Center. Samples were collected from feed source (seawater), and from reject stream (brine discharge point). Samples were analyzed at water department's facility using suitable instrument. The obtained results show differences in most of the measured chemical components between seawater and brine discharge which was highly expected. It was found that brine discharge contained traces of metals such as chromium and none of some other metals such as iron. Therefore, contamination with metals is below a critical level. This can be attributed to the fact that metal equipment is not used in Tajoura RO plant. The major concern of brine discharged from Tajoura plant is represented by its high salinity as its increase from feedwater exceeds by far 1 psu.

Keywords: Desalination technology; Environmental impact; Brine disposal; Water treatment

1. Introduction

Scientists consider water shortage as one of the major challenges that our world is fighting against. People who live in North Africa and the Middle East are the most affected ones by this problem. Places such as Somalia have had recently experienced a very serious dry weather. Drought has killed many people in this country. Some other parts of the world do not have enough potable water although some countries are bordering a sea or an ocean. Extensive work has been done in the last four decades to provide uncontaminated potable water to those who need it. Technologies such as water treatment and desalination were/still the first option when it comes to providing potable water. There are about 15,000 water desalination plants around the world producing 60 million

*Corresponding author.

cubic meters of water on a daily basis. The two-third of this production is in the Arab world [1].

As in most of the Arab countries, Libya is facing a major issue in the demand for clean water. Libya is not only the second largest country in North Africa, but it also has the longest coast on the Southern Mediterranean. According to the reports published by the Water Resources Institute [2], nine countries on the globe are considered to be in water crisis where these countries are consuming water more than it can be replaced. Libya is one of these countries. The main water source in Libya is the groundwater with 90% dependency [3]. The excessive extraction of groundwater sheets observed over the last few decades caused intrusion of salt levels when the sheets are on the coast. On the other hand, a considerable reduction in the average rainfall over the Western part of Libya has made the situation severe where the lost groundwater could not be replaced.

2. Desalination technology in Libya

Using desalination plants to provide potable water has been a limited option in the last few decades around Libya. Building desalination plants with less or no environmental impact would be a crucial answer to meet the great demand for water. In the last ten years, Tajoura has experienced a widespread shortage of drinking water never before seen. Since 2001, the salinity of groundwater has increased significantly [4,5]. It is time for Libya to change focus from spending money to maintain/or extend man-made river project to adopt desalination technology extensively all over its coast. It is time to accept that desalination is the best option for all coastal Libyan cities.

3. Environmental impacts of desalination plants

A desalination plant is similar to any other industrial activity in its potential to cause negative impacts on the environment. Environmental impact produced by desalination plants are due to several aspects such as liquid and solid wastes, gas emission, land use, noise, etc. [6,7].

4. Tajoura desalination plant

Tajoura reverse osmosis plant was built at Tajoura coast in 1984, 30 km East of Tripoli. This plant is the largest of its kind in Libya with a capacity of 10,000 m^3/d. The purpose of this plant was mainly to supply Tajoura Nuclear Research Center (TNRC) located nearby the plant with industrial and drinking water and to partially supply Tajoura town with its needs of clean water. Technical specifications are shown in Table 1 [8].

Unfortunately, due to the pipeline construction delay, service was limited to certain public utilities and desalinated water never reached people of Tajoura until 2003 when the pipeline was eventually constructed.

The plant at the present time is running without technical problems, operating for about two weeks every 45 d with half of its designed capacity which is sufficient to meet the needs of the TNRC. However, the Tajoura desalination plant no longer supplies any residential areas. The quality of produced desalinated water from Tajoura plant has declined due to the fact that membranes have been used for approximately eight years.

During its very long time of operation, there was no serious consideration to evaluate the potential impact of Tajoura desalination plant on the environment. This paper is the first attempt in that direction. It is not the intention of the authors to describe/examine here the effects of brine discharge from Tajoura desalination plant on the fauna, flora, and sea bottom, but rather to analyze the brine discharge composition and evaluate whether it is within the permitted range or exceeds it.

Pre and post-treatments are important steps in the process of seawater desalination. Desalination requires chemical materials in order to treat seawater from substances, suspended solids, scale deposits, biofouling, and to make the water suitable for conveyance in the distribution systems and for portable use [3]. Table 2 lists the chemicals used in Tajoura desalination plant [8].

4.1. Chemical aspects of brine discharge from Tajoura plant

The liquid waste produced in Tajoura reverse osmosis desalination plant is a substantial portion of the treated water with high concentration of salt and other contaminants retained by the process. Rejected liquid waste from Tajoura desalination plant into the sea is expected to consist of different components:

Table 1
Technical specifications in Tajoura reverse osmosis desalination plant

Designed capacity	10,000 m^3/d
Operating capacity (50%)	5,000 m^3/d
Recovery	40%
TDS water product	1,000 ppm
Application	Industrial use

Table 2
List of chemicals and amounts used in Tajoura desalination plant

Chemicals	Doses (mg/l)	Purpose
Copper sulfate	4	Disinfection
Calcium hypochlorite	0.61	Disinfection
Sodium hydroxide	16	pH control
Sulfuric acid	40	pH-adjustment
Ferric-chloride sulfate	2–4	Flocculation
Prastol (A335 F1)	0.78	Flocculation
Sodium pyro sulphite	2.5	Des-oxidation
Special phosphate (AF 200)	5	Antiscaling

flocculants, anti-scaling additives, antifouling additives, oxygen scavengers (sodium sulfite), acid, and finally the concentrate.

The brine rejected from Tajoura desalination plant to some degree is mixed with other effluents before discharging it into the sea. The compositions of these effluents are mainly chemicals which could have undesirable impact on the environment. The chemicals used in the pre and post treatment stages would sometimes be sent away in one of these cases:

(1) At every termination of the plant run, the remaining chemicals would be discharged into the drain which is connected to a manhole where it meets with the brine reject.
(2) All spilled chemicals due to accidental leakages are washed and thrown into the drain.
(3) Lubricating oil used to cool pump's bearings is sometimes replaced by new one and the used oil is discharged into the drain.
(4) There might be some other unfriendly chemical compounds discharged into the drain from either the chemical dosing room or from the workshop. There are no clear indications to confirm this argument as the chemical laboratory in the plant does not have a suitable measuring instrument for such chemicals.

Generally, it is believed that the chemicals produced from the above-mentioned points affect the nature of the concentrated brine and can indirectly dilute it in terms of salinity, but could also increase the contents of some chemicals that brine concentrate already has. In order to confirm this point, two different brine samples were taken from two different discharge points; the first sample was collected from a tap immediately after the turbine before the brine is mixed with any of the other effluents, and the second sample was collected at the discharge point on the sea.

Fig. 1 shows the brine discharge point.

4.2. Experimental

The concentrations of the chemical contents of brine discharged from Tajoura desalination plant were measured using suitable instrument.

4.3. Results and discussion

After analyzing the samples, the difference in the chemical compositions between the two brine samples became clear, which confirmed our argument regarding the dilution. However, the concentrations of some chemical elements have stayed almost the same or changed slightly and this can be clearly ascribed to

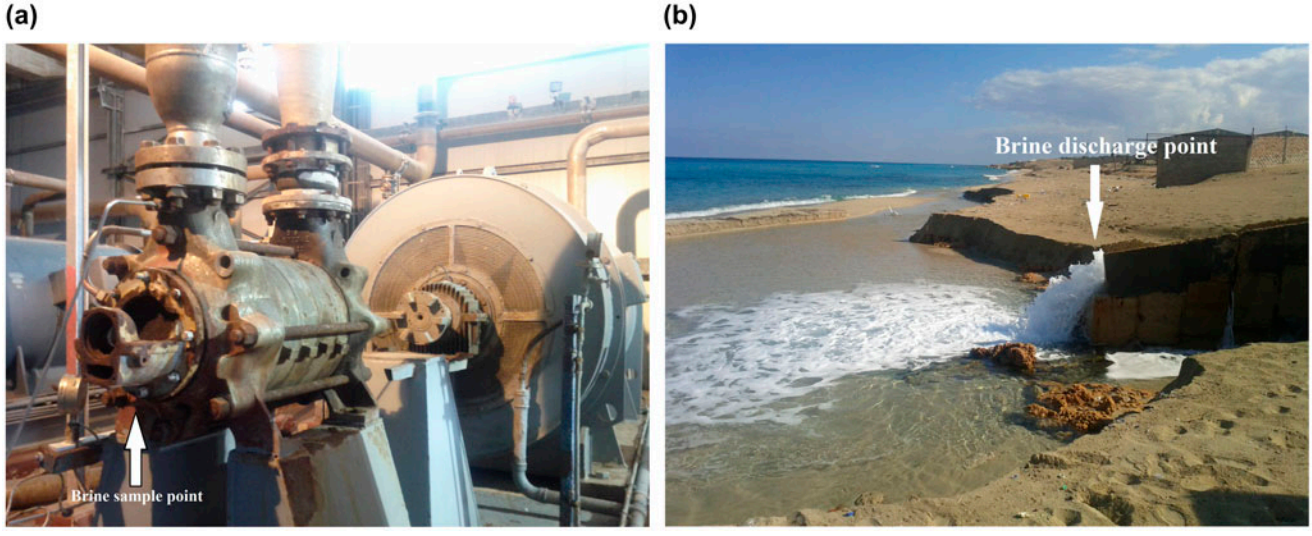

Fig. 1. Brine sample points. (a) After turbine; (b) discharge point at the sea.

the fact that these chemical elements were not involved within the chemicals introduced to the brine concentrate from other effluents.

Table 3 shows the chemical contents of seawater and brine reject in Tajoura plant.

As expected from the literature, the chemical content of brine is higher than that of seawater. Generally, the salts returned to the sea are identical to those present in the feedwater, but they are now present at a higher concentration [9,10]. Table 3 shows that the brine produced from Tajoura seawater reverse osmosis plant have up to 39% more salt concentration than the receiving water.

The obtained results showed that brine concentrate contained traces of metals such as copper, chromium, manganese, and silicon. All detected trace elements are present in concentrations less than 0.5 mg/l. Therefore, those metals do not contribute to the salinity or to the environment.

It should be noted that the increase in the concentration of ions such as sodium, calcium, potassium, and sulfate in the brine discharge as it is the case in this study, does not imply an adverse effect on the environment. However, the increase in chloride can be toxic to trout and other fish species [11,12].

The analyses showed that seawater contains certain amount of carbonate. However, brine discharge does not seem to have any carbonates. One possible reason for the presence of carbonate in seawater is that seawater contains dissolved phosphorus compounds or/and magnesium solution. These compounds can inhibit calcium carbonate ($CaCO_3$) precipitation [13]. In addition, naturally occurring organic compounds inhibit reactions between carbonate minerals and seawater [14].

The major concern of brine discharged from Tajoura plant is represented by its high salinity as its increase exceeds by far 1 psu. It was experimentally proved that salinities of 40–45 psu appear to cause significant increases in the mortality of exposed plants, epifaunal mysids, and echinoderms [15]. Although, the salinity of Tajoura brine concentrate plume exceeds 45 psu, and it will be reduced as soon as it reaches the sea. A serious consideration should be taken regarding the brine concentrate discharge point. The current brine discharge point is surrounded by rocks which are rich in organisms. Therefore, its high salinity endangers these living creatures.

It has to be mentioned that there are some recreation activities such as summer resorts taking place nearly all the way along Tajoura coast during summer season (from May till end of September). The coast where the Tajoura desalination plant is located is no exception to this phenomenon. Therefore, there are some summer resorts on the coast where the brine discharge point is located. Local traditional summer resorts include living facility; tents, small rooms made of wood, toilets, and showers. People from Tajoura and other Libyan cities come with families to enjoy their time in these resorts.

When the samples were collected from the discharge point at Tajoura coast, some people were seen swimming in front of the brine discharge plume. People who were seen in front of the direct discharge point neither thought that this water is different from seawater nor that it is coming from another source.

Table 3
Chemical composition of seawater and brine reject in Tajoura plant

Element	Seawater (mg/l)	Brine (mg/l)	Instrument used
TDS	37,050	49,330	pH-conductivity Benchtop
Salinity	37,900	52,600	pH-conductivity Benchtop
Sodium	13,230	17,800	Flame Photometer (BWB XP)
Calcium	420	1,160	BWB XP
Magnesium	1,740	580	BWB XP
Potassium	452	610	BWB XP
Chloride	22,500	30,840	Standard titration method
Sulphate	2,800	4,330	Spectrophotometer (HACH DR 2800)
Nitrate	0.53	1.07	HACH DR 2800
Carbonate	39	None	Standard titration method
Bicarbonate	134	22	Standard titration method
Silicon	0.25	0.7	HACH DR 2800
Copper	0.30	0.45	HACH DR 2800
Iron (Fe^{2+})	>0.009	>0.009	HACH DR 2800
Chromium (Cr^{6+})	0.107	0.21	HACH DR 2800
Manganese	0.2	0.45	HACH DR 2800

One can justify why some people choose to swim in front of the brine discharge point because the area around the discharge point is very clean, and it's very convenient for elderly people to swim in. Some other people go too far and think that swimming in front of the brine discharge point can heal from skin diseases. This thought is not based on any real medical knowledge or any scientific study.

5. Conclusion

The experimental results reported in this study showed that the chemical composition of the brine discharged from Tajoura reverse osmosis plant are within the limits recommended by the Libyan Environmental General Authority, 1982. Additionally, these concentrations will be further decreased as they mix with seawater.

Detected trace heavy metals such as copper and chromium are present in seawater and brine concentrate in low concentrations. Therefore, these metals do not contribute to the salinity or to the environment.

6. Recommendation

As it is considered to be the first serious piece of work that concerns the brine discharge from Tajoura plant on the South Mediterranean, it is highly recommended by the authors for further investigations of brine's salinity and its impact on the fauna, flora, and sea bottom.

Further investigations should be done to investigate the effect of the brine concentrate at different distance from the coast.

There should be a serious talk concerning relocating the brine discharge point or at least to make the area surrounding the discharge point inaccessible for the public especially in summer time.

It is essential that researchers involved in the environmental impact of all desalination plants in the Libyan coast, and Tajoura plant in particular, be supported and encouraged to publish their results in well-known journals to further advance knowledge in this area.

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