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Environmental implications of Tajoura reverse osmosis desalination plant

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ABSTRACT

Water resources in North Africa are limited and do not meet the future water demand. The water shortage is very severe in Libya which is located in a semi-desert region. The available water resources in Libya are mainly the groundwater which is not enough to meet its people needs due to many reasons, among them is seawater intrusion. Desalination of seawater is one of the main alternatives for the substitution of water shortage in Libya and other North African countries. Despite the fact that desalination technology is an important option for providing potable/industrial water, it has some negative impacts on environment. High concentrated brine discharges from desalination plant is the main cause of negative impacts. Noise, visual impact, air pollution, impact on the aquifer, and disturbance of recreation areas are other environmental impacts on a more local scale. The aim of this study was to highlight the environmental impacts of Tajoura reverse osmosis desalination plant on the local environment. The findings of this study reveal that the most concerning issues identified from the existing Tajoura RO desalination plant are brine concentrate, noise pollution, and chemical hazards.

Keywords: Desalination; Reverse osmosis; Brine disposal; Noise pollution; Environmental impacts

1. Introduction

Despite the fact that Libya has the largest coast on the Southern Mediterranean Sea (1,950 km), desalination technology is not being widely used in Libya as a main source of providing clean water. The previous government adopted Man-Made River project (MMRP) to be an alternative for groundwater shortage in the Northern side of the country. The vision of this project was to bring water from huge aquifers in the south to coastal cities and desert towns via very long pipelines. Since the MMRP has some difficulties to reach many districts and towns in the north such as Tajoura, the MMRP did not achieve its full target. Although some coastal cities were supplied with water from MMRP, people feel skeptical about the quality of the water. Therefore, a large percentage of the population in the big cities such as Tripoli, Benghazi, and Misurata do only use this water for washing, cleaning, and agriculture but never for drinking. The doubt of the quality of MMRP freshwater is being not good enough for drinking came up as people think that the water which is collected in big reservoirs is not analyzed or treated regularly which could make it does not meet the standards of drinking water. Due to the current situation of MMRP, water shortage is still a continuing problem in most of the Libyan land. National committee has recommended that environmentally friendly desalination technology should be taken seriously into account to be the main option for solving the water shortage crisis in Libya. For that reason, the author intends in

this study to highlight the environmental implications of an old local operating desalination plant in order to gain information that can be useful and helpful for constructing a new and bigger desalination plant nearby the old plant.

2. Case study: Tajoura RO desalination plant

2.1. Plant description

Tajoura reverse osmosis desalination plant is one of the main plants in Libya. The plant is located at the coast of the Mediterranean Sea, as it can be seen in Fig. 1. The plant produces 10,000 m^3/d of clean water which makes it the largest production of desalinated water in Libya using reverse osmosis membranes (RO technology). In spite of the plant has been running for almost 30 years, there has not been any investigation of any kind to examine or evaluate its negative impacts on the environment. In this study, we will review some environmental aspects of Tajoura desalination plant. The study will attempt to highlight some major environmental concerns include issues related to location, chemical hazards, noise, and concentrate disposal of Tajoura desalination plant.

2.2. Process description

Fig. 2 shows a schematic diagram of the Tajoura RO desalination plant. Seawater is fed by gravity through two plastic pipes of 760 mm in diameter into a seawater basin with a capacity of 1,920 m^3. Seawater is then pumped to a pre-treatment system (flow rate = 1,576 m^3/h for full operation). The pre-treatment system consists of 8 dual media filters and 5 μ cartridge filters and chemical dosing system. Dual media filters are composed of three layers: sand at the bottom, gravel at the middle, and anthracite at the top. Chemicals are dosed online on a pre-treatment system before seawater enters the dual media filters and before cartridge filter. The chemicals used in the pre-treatment stage of Tajoura plant are mainly:

Fig. 1. Location of Tajoura desalination plant (Source: Map data: Google, © 2015 DigitalGlobe).

(1) Copper sulfate ($CuSO_4$) used for disinfection.
(2) Sulfuric acid (H_2SO_4) used for pH adjustment.
(3) Sodium pyrosulfate ($Na_2S_2O_5$) used for deoxidation.
(4) Ferric chloride sulfate ($ClfeSO_4$) used for the flocculation and removal of suspended matter from water.
(5) Special phosphate (AF200) used as antiscalant to inhibit calcium sulfate ($CaSO_4$) precipitation on the surface of the RO membranes. Antiscalants are added before the cartridge filers.
(6) Sodium hydroxide (NaOH) used for pH adjustment.
(7) Calcium hypochlorite [$Ca(ClO)_2$] solution used for preventing biological growth.

After the pre-treatment stage, water is pumped to the RO membrane system. Tajoura RO desalination plant consists of two RO stages in two lines. The first RO stage consists of four racks with 99 pressure vessels each. Each pressure vessel contains six spiral wound RO membrane. The design recovery rate of the plant is 30%. Product water of the first stage is collected in the buffer tank (volume = 50 m^3). Water from the buffer tank is then pumped by high-pressure pumps to two second stage racks. Around 85% of the produced water from the first stage is recovered by the second stage and collected in a storage tank for further post-treatment. However, the brine concentrate from the second stage is recycled back and mixed with the feed to the first stage.

3. Environmental aspects of Tajoura desalination plant

The following sections identify potential environmental aspects of Tajoura desalination plant.

3.1. Land usage by the desalination plant of Tajoura

(1) Tajoura RO desalination plant is located in an area called Byaar Elsbabeel, 10 km from the town center. This location was at the time a good choice for constructing the plant for some reasons.

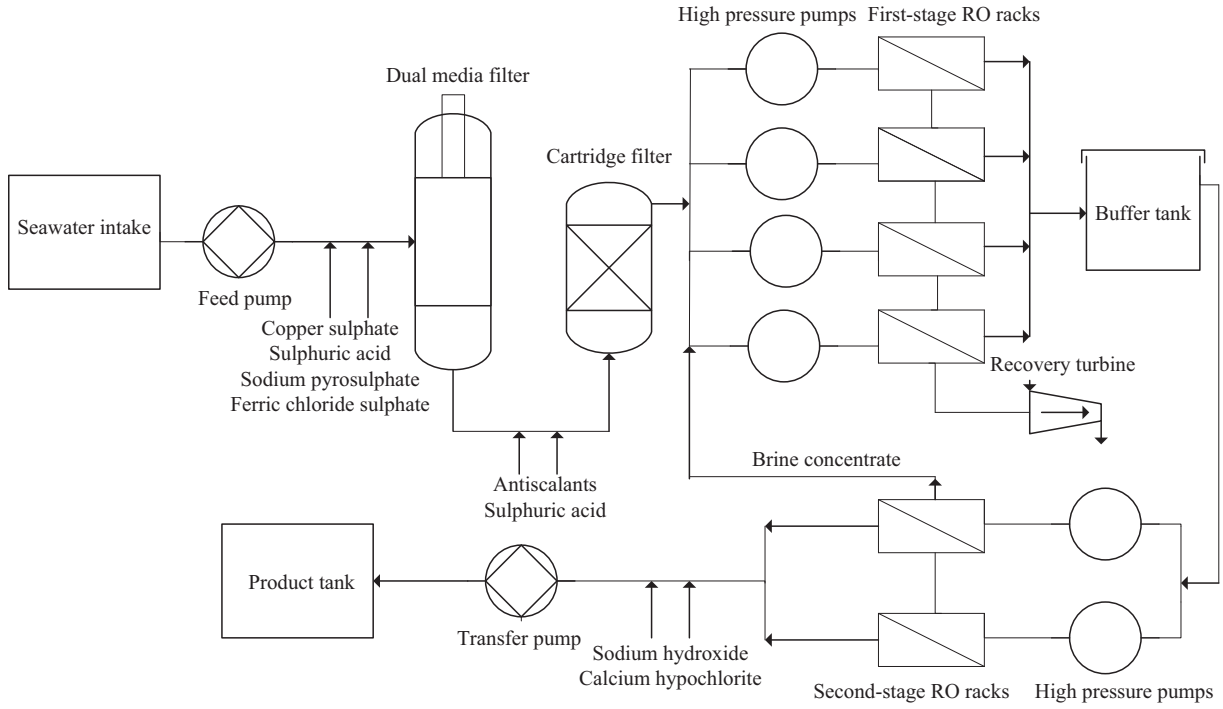

Fig. 2. Schematic diagram of the Tajoura RO desalination plant.

(2) It is next to the sea, this advantage keeps the quality of the raw water safeguarded. The proximity of seawater and brine transfer reduced the risk of land pollution.
(3) It is next to the nuclear research center in which can be provided with water.
(4) The raw water seems to be of good quality since the intake is located away from any ports or points of discharge of water of questionable quality.
(5) Long way from the main residential areas. Recently, some changes were created nearby the area, small village of 200 people is built in the neighborhood (~1,000 m from the plant).

The land used by the Tajoura desalination plant and its all facilities is around seven hectares divided as follows: (1) the approximate area used by the main buildings is one hectare. This area excludes the intake, chemical storage department, and the produced water tank. (2) half a hectare used by the chemical storage department, (3) one hectare used by the produced water tank, (4) one hectare used by the intake, (5) around one hectare used by the electricity grid mix and under-construction thermal desalination plants. The remaining two and a half hectares are considered as greenery area that surrounds the plant and its ancillary facilities.

3.2. Visual impacts of the plant

The infrastructure design of Tajoura desalination plant at a lower bench level which is environmentally convenient does not cause any visual impact across the coastal plain. The plant is also surrounded by landscape planting from three directions: south, east, and west. This makes the plant has low visibility on the surrounding area.

The lighting levels at Tajoura plant are kept at certain level which is required for operation and safety. This prevents any impact from lighting. The plant roofs were not made of any reflective materials that could cause any environmental impacts.

3.3. Pipeline system

The route of the pipeline to transfer raw water from the sea to the desalination plant and discharging the concentrated brine from the plant back to the sea is installed underground without any visibility, thus prevents any visual impacts but could cause impacts on the aquifer if there are some leakages.

Based on the available documents on the plants, there has not been any leakage from the transferring pipes. Thus, maintenance has not been required. Received information from operators and engineers

work on the plant state that there was no any monitoring devices attached to the piping system during installation.

3.4. Noise and vibration emissions

Noise is generally defined as unwanted or undesirable sound. Sound (noise) levels are usually measured in decibels (dB). Decibel levels range from 0 to 140. Community noise levels are measured in terms of the A-weighted sound level (dBA). The A-weighted scale adjusts the measured sound levels to generally correspond with the way the human ear responds to sound. A civil defense siren would have an A-weighted sound level of 130 and be above the threshold of pain if a receptor was standing less than 100 feet away. On the other hand, soft whispering would have an A-weighted sound level of 30 and barely be audible [1,2].

Excessive noise can not only be undesirable but may also cause physical and/or psychological damage. The amount of annoyance or damage caused by noise is dependent basically on three factors: the amount and nature of the noise, the amount of ambient noise present before the intruding noise, and the activity of the person working or living in the noise source area.

As any other industrial plant, Tajoura reverse osmosis desalination plant could be a source of noise. The noise generated in a reverse osmosis desalination plant is mainly produced by the high-pressure pumps and the turbines used for energy recovery [3–5].

There are six high-pressure feed pumps in Tajoura RO plant with four pumps feeding the first stage and two pumps feeding the second stage. These pumps generate the pressure required for desalination. Currently, Tajoura plant is operated with only three pumps as the other three pumps are out of service. Two high-pressure pumps named 401 and 402 are used for feeding the first stage, and one pump named 411 is used for feeding the second stage. Fig. 3 shows one of high-pressure pumps used in Tajoura RO plant. The major design parameters of the first stage high-pressure feed pumps are the following:

Manufacturer	KSB, Germany
Type	HDAO 150
Pumping medium	Seawater
Flow rate	394 m^3/h
Pump efficiency	76%
Working pressure	71 bar
Construction	Horizontal type, multistage, with vertical split casing
Power required	1,040 kW

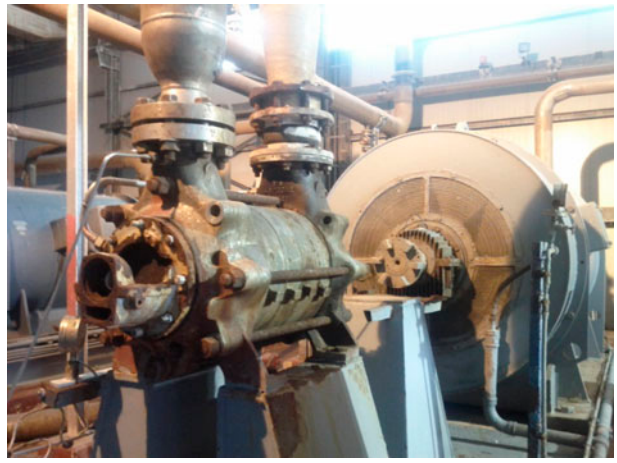

Fig. 3. High-pressure pump used in Tajoura plant.

The major design parameters of the second stage high-pressure feed pump are the following:

Manufacturer	KSB, Germany
Type	HDAO 150
Pumping medium	Permeate of second stage
Flow rate	275 m^3/h
Pump efficiency	72%
Working pressure	45 bar
Construction	Horizontal type, multistage, with vertical split casing
Power required	500 kW

The only study done for noise generated from the high-pressure pumps at Tajoura RO desalination plant was conducted by a group of engineers and technicians from the Tajoura Nuclear Research Center [TNRC] supervised by Azzam Helmi [6]. The finding results of this report were our main source of information for this section.

Noise level was measured at different sites inside the main building of the plant. Measuring sites included the high-pressure pumps housing, the main hall, the laboratory, injection room, workshop, bed room, kitchen, and some other sites as shown in Fig. 4.

Noise measurements were conducted along the proposed sites as shown in Fig. 4 to determine the approximate ambient noise level. The noise measurement results are illustrated in Table 1.

Noise level measurements shown in Fig. 4 and Table 1 indicate that the greatest noise levels were found to be at the high-pressure pumps housing. Noise level reached to 101 dBA between and around the pumps. The second highest noisy sites among the measured sites were in the main hall where the membrane modules are placed. One of the obvious reasons

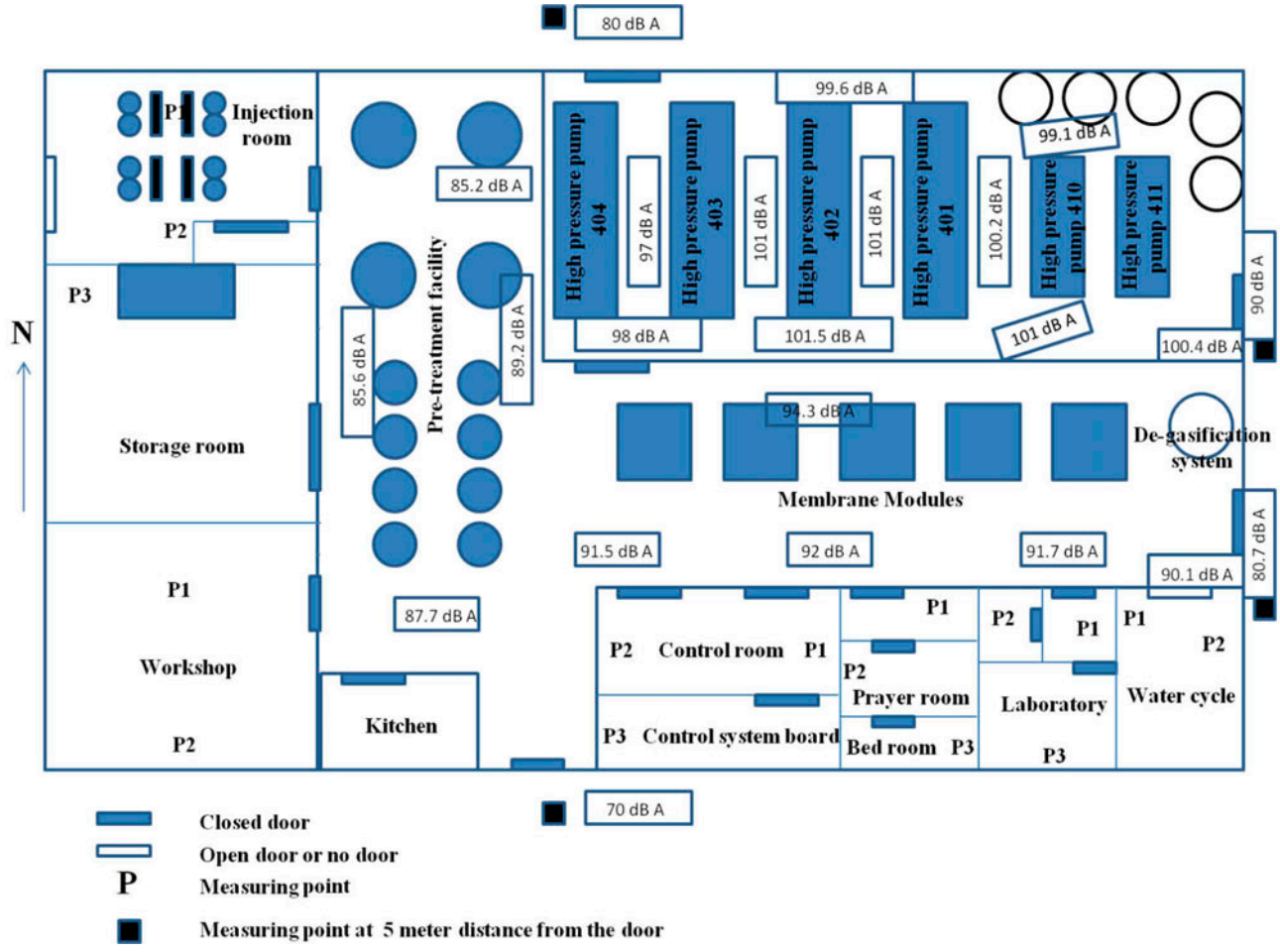

Fig. 4. Noise measurements at different sites at Tajoura plant.

Table 1
Summary of noise levels at different sites in Tajoura RO plant

		Noise level dBA Measuring site					
		Door					
		P1		P2		P3	
Position	International standard [7,8]	Open	Closed	Open	Closed	Open	Closed
Control room	60	80.6	70.3	82.6	70	67.5	66.5
Laboratory	–	85	73.2	78.5	68.5	75.3	62
Injection room	–	73	1.3	74.5	70.1	70.8	69.5
Bed room	55	81	68	71	57.4	68	55.5
Workshop	70	75.6	70.3	74	69.8		
Kitchen	60	82	79.8				
Water cycle	60			82			

of high noise level at this site is that RO membrane racks are placed in close proximity to the high-pressure pumps housing. Kitchen, bed rooms, laboratory, control room, workshop, and injection room were found less nosy sites; however, noise levels at these specific sites are still higher than the international standards set for noise exposure as presented in Table 1.

The nearest sensitive receptors with regard to noise are operators who are working inside the above-mentioned sites. On the other hand, the noise has no or very low effect on the outside environment as the plant is surrounded by a green buffer (trees) from three directions.

3.5. Chemical hazards

Another important issue concerning workers and operators in Tajoura desalination plant is chemical storage department. The first negative sign that can be clearly noticed in Tajoura plant regarding the chemical storage department is its location, whereas it is located within the range of few hundred meters from the operation units. The second and the most dangerous aspect are the miserable conditions of the storage department. The storage department is unorganized, and full of unused, and expired chemicals, some of which are very toxic.

The way of storing the chemicals in Tajoura desalination plant would create a significant hazard to the employees and/or the environment through accident conditions involving accidental spill, and the release of hazardous materials into the environment. Pictures on Fig. 5(a) and (b) talk for themselves.

3.6. Public safety

Operating Tajoura desalination plant would involve the use of several chemicals that have the potential to adversely affect human health if they are accidentally spilled or released and subsequently come into contact with operational personnel. Many of the chemicals to be transported, stored, and used during plant operations would have significant consequences if spilled. The primary concerns would arise for spills of sulfuric acid, aqueous ammonia, sodium hypochlorite solution, or calcium carbonate. According to the duty manger, there has not been any accidental spill reported during his working period. However, operational personnel have some complaints regarding the strong foul odors that remain on the environment for long time after adding chemicals.

3.7. Brine disposal point

Brine disposal is a liquid waste from a desalination plant, which contains a high content of salts and dissolved minerals as well as remaining chemicals used for pre-treatment and post-treatment stages. It returns back to the sea and spreads according to different

Fig. 5. Chemical storage department at Tajoura desalination plant: (a) acid is spilled in the floor and (b) dust is all over the place.

Fig. 6. Brine disposal point at Tajoura plant.

Table 2
Chemical doses used in Tajoura desalination plant. Prepared by the author

Chemical doses	kg/m^3	ppm
$CuSO_4$	0.026	4
NaOH	0.026	16
H_2SO_4	0.16	40
Flocculant	0.015–0.031	2–4
Antiscalant	0.125	5
Deoxidant	0.019	2.5

aspects. The pre-treatment chemical agents are important to consider because they remain in the concentrate before disposal [4]. Tajoura RO desalination plant discharges brine directly to the sea. The disposal point as can be seen in Fig. 6 is placed exactly on the beach [coastline]. The amount of chemicals used in the pre-treatment stage in Tajoura RO desalination plant is shown in Table 2.

A recent publication done on the brine discharge from Tajoura RO desalination plant showed that brine concentrate contained minor amounts of metals such as copper, chromium, manganese, and silicon. All detected trace elements are present in concentrations less than 0.5 mg/l; therefore, no pollution or contamination problems are expected from these metals [9]. However, among all chemical ions discharged with brine concentrate, chloride can be toxic to the marine species [10,11].

According to Brika et al. [9], the major concern of brine discharged from Tajoura plant is represented by its high salinity as its increase exceeds by far 1 psu (1 psu = 1 ppt). Although the salinity of Tajoura brine concentrate plume exceeds 45 psu, it will be reduced as soon as it reaches the sea. Table 3 summarizes the brine composition as obtained from a previous work done on Tajoura RO desalination plant.

Table 3
Chemical composition of brine reject from Tajoura desalination plant

Element	Brine (mg/l)
TDS	49,335
Salinity	52,600
Sodium	17,788
Calcium	1,160
Potassium	608
Chloride	30,841
Sulfate	4,333
Nitrate	1.07
Silicon	0.7
Copper	0.45
Iron (Fe^{2+})	<0.009
Chromium (Cr^{6+})	0.21
Manganese	0.45

Environmentally, the site of the brine disposal point is not considered to be the right place for discharging large amount of high concentrated seawater. It would have been desirable to place the point of brine disposal far away from the beach and from rocky areas which are rich in organisms, as well as far away from areas where are certain activities take place

Fig. 7. Swimming in front of the brine discharge point at Tajoura coast.

in special occasions such as summer resorts which is the case here in Tajoura coast from mid of May till end of September. As can be seen clearly in Fig. 6, there is a camping tent placed just on top of the brine disposal pipe. During summer time, people were seen swimming in front of the brine disposal point without having knowledge about the negative impacts that can be caused by doing this activity in such a place (Fig. 7).

In addition to what is mentioned above, there should be serious impacts on the marine biota in the vicinity of the outlet of discharge pipe and would be related to the increase in the concentration of salt. No investigation, whatsoever, was done in this regard as it is beyond the scope of this study.

3.8. Cultural resources

Each country assesses the cultural impact according to different aspects, including historical and archaeological values. Other indicators include local culture, economics, religion, and architecture [12]. Despite the fact that these aspects are protected by the Law no. 7 [Libyan Environment Protection Law], the old Libyan regime did not place any special emphasis on archaeology and historical sites. Furthermore, many historical places had to be deliberately buried, and in some cases were badly destroyed.

The surroundings of Tajoura RO desalination plant were surface surveyed and some cultural resources sites were identified. As a result, operating process at Tajoura RO desalination plant during the last three decades has affected the archaeological sites. Apparently, the absence of implementation of any environmental regulations and mitigation measures has increased plant's impacts on these sites significantly.

Fig. 8. A Crypt found nearby Tajoura plant.

A new site believed to have a significant cultural/archaeological importance has been observed recently, although no related concrete evidence whatsoever was found yet. Additionally, this site has never been investigated, tested, or studied by any historians or archaeologists. Therefore, there are no any available written reports or documents to learn about this site.

The history of Tajoura is rich in cultural materials as it was described in some archaeologists' books. The author believes that the new crypt (Fig. 8) discovered recently might has an important key history for the Roman period of Tajoura. Unfortunately, no great deal of attention was devoted to such an important site. Accordingly, the crypt can be damaged by any ground disturbing activities, thus serious actions should be taken urgently.

Some other small and less significant cultural materials were noted in others parts of the area surrounding Tajoura plant.

4. Conclusions

The desalination technology has never been one of the main sources for portable water in Libya; therefore, there has never been so much discussion on its environmental impacts. The following points can be extracted from this study:

(1) High-pressure pumps and energy recovery system, such as turbines in Tajoura desalination plant produce significant level of noise and are not provided with equipment to reduced noise level. Therefore, these machines should be equipped with appropriate technological means for reducing the noise level. Building of canopies over the pumps is one of such means. Furthermore, a serious action should be taken soon and health care and acoustic devices should be provided to all of those who are affected by this contamination.
(2) Chemical storage department is a big concern for people work in the plant. The chemical storage department should be reorganized, used membranes, unwanted chemicals have to be dealt with carefully.
(3) Depending on the current conditions of the surroundings, the location of the brine discharge point is not appropriate because of the interference of the mixing zone with recreation on the beach. Therefore, serious action should be taken regarding relocating the brine disposal point or making it inaccessible to public.

(4) There is a huge lack of information among local people who live in the nearest village to Tajoura desalination plant. This can be attributed to many reasons: the village was built after constructing the plant, there was no qualified people from the plant, or any other social organization who dealt with the local community intensively in order to educate them environmentally.

5. Recommendation

Recreational activities such as summer resorts, fishing, and boating are to be taken place away from the plant. The responsible people of the plant and the nuclear research center in Tajoura should take a serious action by making restricted boarders for the intake area, brine discharge point, as well as other waste disposal points from both sources.

There should be an intensive study concerning the effect of brine disposal from Tajoura desalination plant on marine life.

There should be a serious cooperation between the management of Tajoura Nuclear Research Center [TNRC] and the National authority of Historic Places to evaluate and preserve the new historical observed sites around Tajoura desalination plant.

Acknowledgment

The author would like to thank all workers in Tajoura RO desalination plant for their assistance during the course of this work. They showed a very serious care to the environment and have the desire to work intensively in order to keep the plant running with no or less negative impacts on the environment.

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