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Case study

Geochemical Assessment of Drinking Water: A Case Study of The BO Traba Seawater Desalination Plant

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Abstract
In this work, we performed a geochemical assessment of water collected from the main collection tank of the Bo Traba Desalination Plant. The aim of this work is to determine the suitability of the studied water for drinking purposes. According to the TDS classification, the studied water is classified as desirable for drinking water. The Schoeller, Stiff and Piper diagrams showed that the water samples belong to the $CaHCO_3$ type. The pH in the studied water ranges from 6.65 to 6.92 is acidity water and it is classified as mainly somewhat corrosive. The values of total dissolved solids, total hardness, alkalinity, major ions and environmentally sensitive elements suggested that the studied water is safe for human consumption.

Keywords: *Hydrochemistry, Drinking Water, Bo Traba Desalination Plant, Libya.*

1. Introduction

The Man-Made River Project is the main source of water for most regions in Libya. Areas that are not supplied by the Man-Made River obtain water using seawater desalination or household wells. The Bo Traba Desalination Plant is located in northeast Libya (Fig. 1). The objective of establishing the plant in 2007 is to provide water to the residents of Al Marj, Tulmithah and Tukrah villages. The total area of the plant is about 16 ha. The design capacity of the plant is about 40,000 m^3/d using Multiple Effect Distillation (MED) units.

Lachhab *et al.*, (2019) evaluated the drinking water quality in the Bo Traba Desalination Plant. They found that the water has high specifications compared to the standard Libyan drinking water limits. The goal of the current work is to identify the water quality in the Bo Traba Desalination Plant and assess its suitability for human consumption. To achieve this goal, we determined the concentration of major ions and environmentally sensitive elements in the water of the main collection tank. The concentration was compared with the WHO (2018). The difference between this study and Lachhab *et al.*, (2019) is that we analyzed numerous environmentally sensitive elements such as Fe, F, Pb, Hg, As, Cd, Cu, Zn, Cr, Ni, Br, Ba, Se and U, while Lachhab *et al.*, (2019) analyzed Fe and Cu.

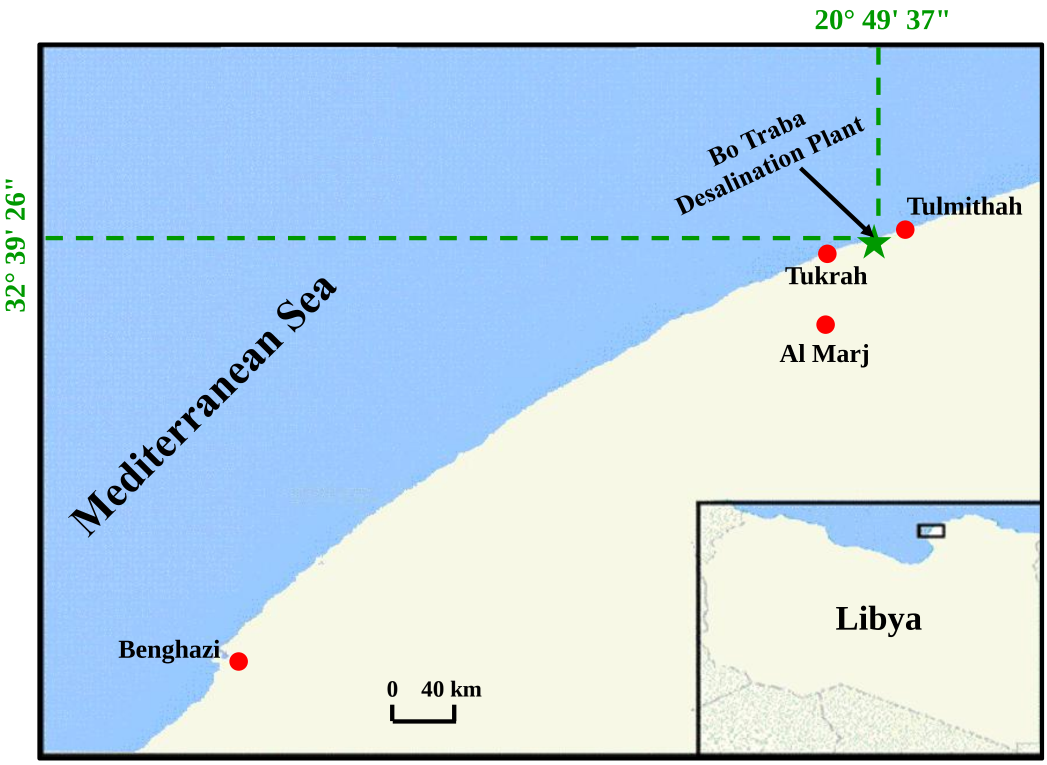

Fig. 1: Location map of the Bo Traba Desalination Plant.

2. Methodology

Four water samples were collected from the main collection tank of the Bo Traba Desalination Plant. To determine total dissolved solids (TDS) and potential of hydrogen (pH), Denver Instrument Model 50 was used. Moreover, to measure major ions and environmentally sensitive elements, inductively coupled plasma-mass spectrometry (ICP-MS) was performed on the samples. The chemical analysis was done in the National Water Research Center, Ministry of Water Resources and Irrigation of Egypt.

3. Results and Discussion

3.1. Hydrochemistry

The chemical analysis data of the studied water is shown in Table 1. In should be noted that the total hardness (TH) and alkalinity (Alk) were calculated as:

TH (mg/l $CaCO_3$) = 2.5 Ca (mg/l) + 4.1 Mg (mg/l)

Alk = $[HCO_3^-] + [OH^-] + 2[CO_3^{2-}]$

A Piper diagram is a simple and widely used method for determining the type of groundwater (Li, P.Y.,2016 and Wu, *et al*., 2018). In this study, a Piper triangle consists of a diamond and two triangles, in which the diamond is divided into nine regions. The diamond shows the general hydrochemical characteristics of the water sample, while the triangle shows the relative content of each ion. Generally, there are six facies of water which are the following;

1) Type I (NaCl Type).
2) Type II ($CaHCO_3$ Type).
3) Type III ($NaCaHCO_3$ Type).
4) Type IV (CaMgCl Type).
5) Type V (CaCl Type).
6) Type VI ($NaHCO_3$Type).

The Piper diagram (Fig. 2) indicates that the water of the Bo Traba Desalination Plant is of Type II ($CaHCO_3$ Type). The Schoeller and Stiff diagrams (Fig. 3) further support this assumption.

Table 1: Chemical analysis data (concentrations in mg/l) of the water collected from the main collection tank of the Bo Traba Desalination Plant

Parameters	Sample No.			
	B1	B2	B3	B4
pH	6.70	6.88	6.65	6.92
TDS	65	61	63	65
K	8.38	8.11	7.75	7.00
Ca	36.00	34.27	33.70	35.66
Na	1.34	1.05	1.62	1.15
Mg	1.91	2.88	3.00	2.74
Cl	17.45	17.21	17.89	17.23
HCO_3	54.09	59.38	56.51	57.67
SO_4	10.21	9.89	10.05	9.60
NO_3	0.01	0.01	0.01	0.01
TH	97.83	97.48	96.55	100.38
Alk	55.47	61.67	57.79	60.11
Fe	0.09	0.09	0.09	0.09
F	0.10	0.08	0.05	0.05
Pb	0.003	0.003	0.003	0.003
Hg	0.0001	0.0001	0.0001	0.0001
As	0.001	0.001	0.001	0.001
Cd	0.0001	0.0001	0.0001	0.0001
Cu	0.90	0.81	0.77	0.84
Zn	0.67	0.80	0.62	0.55
Cr	0.0001	0.0001	0.0001	0.0001
Ni	0.003	0.003	0.003	0.003
Br	0.0001	0.0001	0.0001	0.0001
Ba	0.0007	0.0007	0.0007	0.0007
Se	0.002	0.002	0.002	0.002
U	0.001	0.001	0.001	0.001

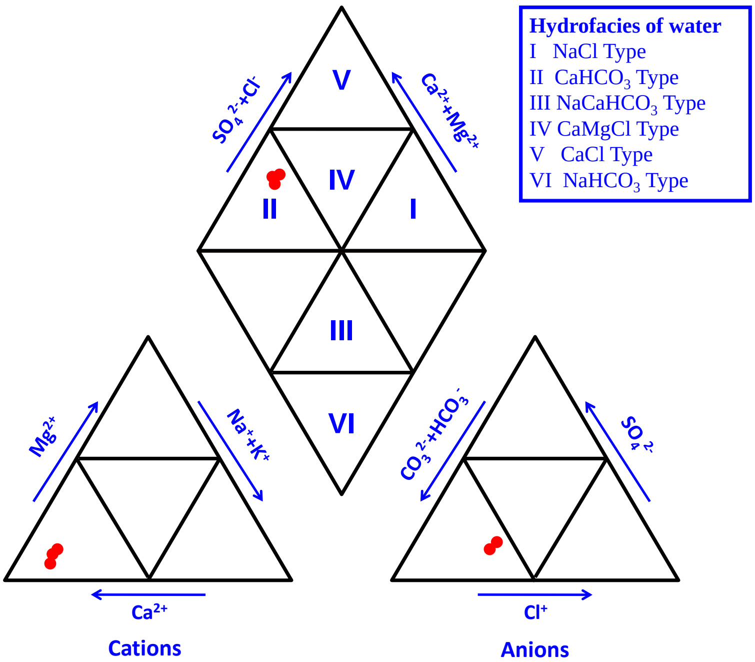

Fig. 2: Piper diagram showing the hydrochemical facies of the studied water (fields after Tweed *et al.*, 2005).

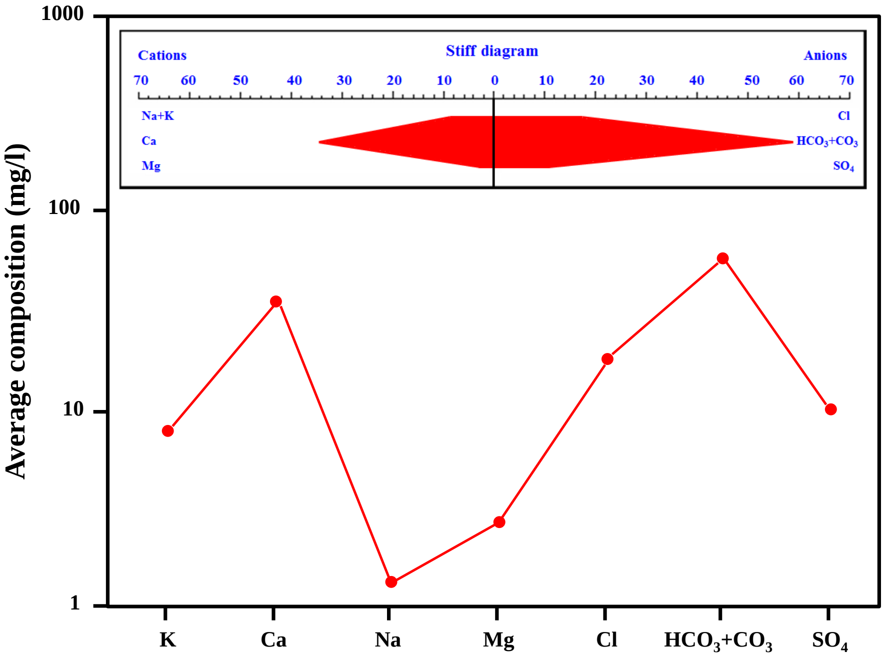

Fig. 3: Schoeller and Stiff diagrams showing the average chemical composition of the studied water (Schoeller, H.,1977).

The binary plot of $Cl/Cl+HCO_3$ versus TDS (Fig. 4) suggests that rock dominance strongly affect the chemical composition of the studied water. Furthermore, the binary plot of Mg/Ca versus Na/Ca (Fig. 5) points to limestone dominance. The ternary plots of Na/1000-K/100-√Mg and $Cl-SO_4-HCO_3$ (Figs. 6 and 7) can be used to define water maturity (Giggenbach, 1988). These plots suggest that the main collection tank of the Bo Traba Desalination Plant contains immature water.

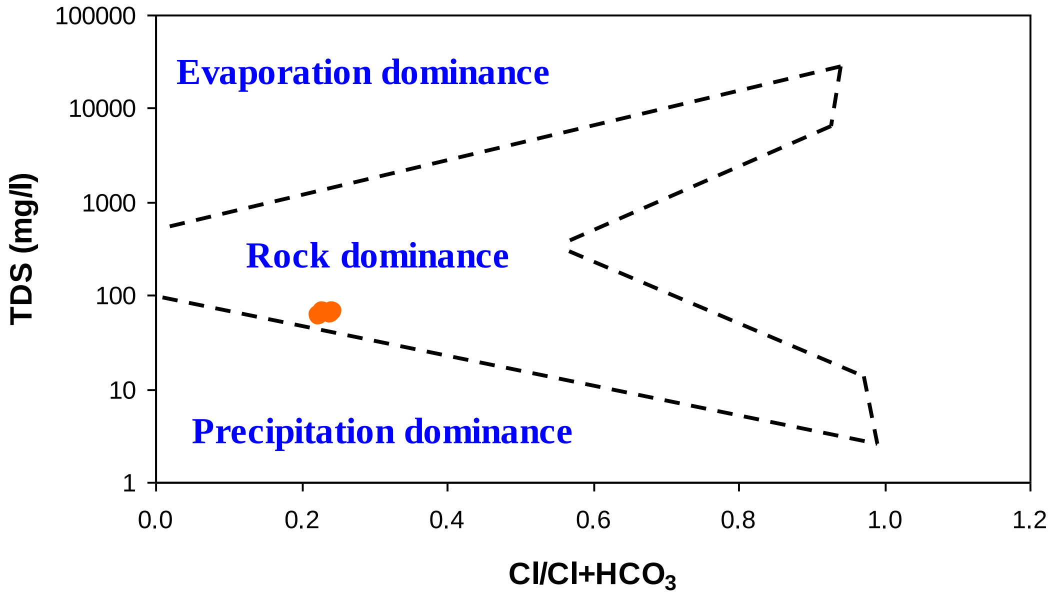

Fig. 4: Binary plot of $Cl/Cl+HCO_3$ vs. TDS showing rock dominance in the studied water (fields after Gibbs, 1970).

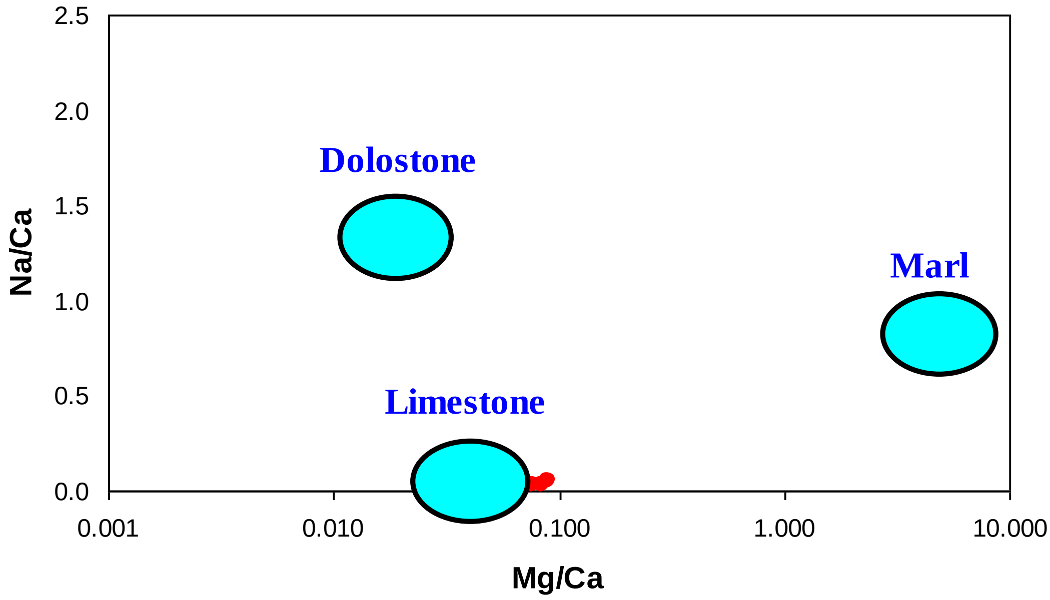

Fig. 5: Binary plot of Mg/Ca vs. Na/Ca showing limestone dominance in the studied water (fields after Han and Liu, 2004).

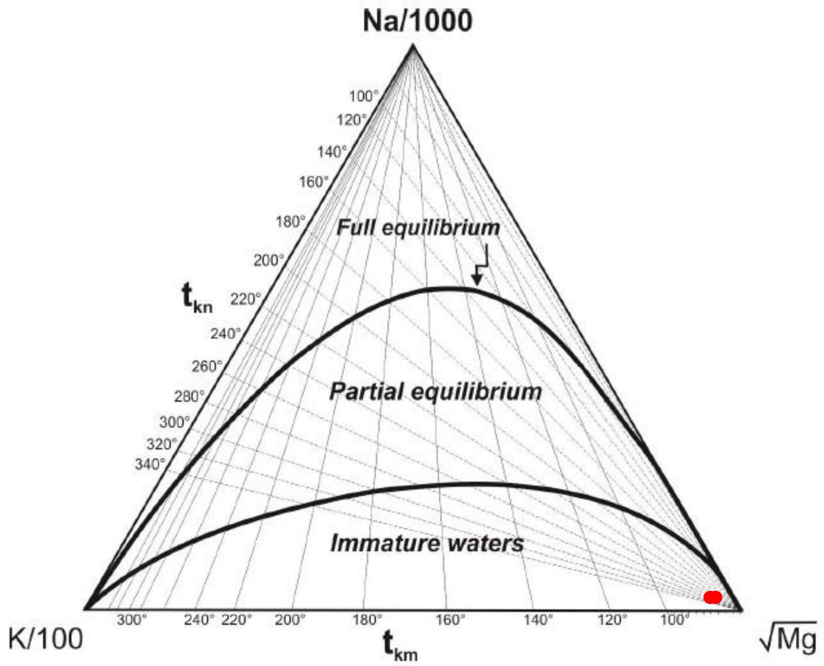

Fig. 6: Ternary plot of Na/1000-K/100-√Mg showing the maturity of the studied water (fields after Giggenbach, 1988).

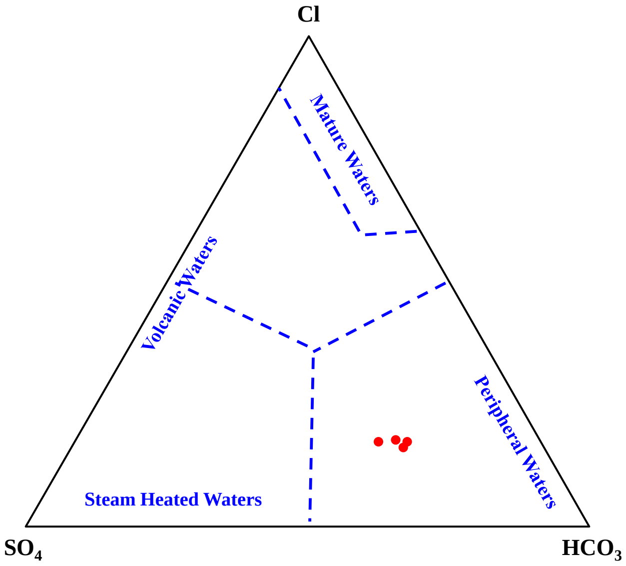

Fig. 7: Ternary plot of Cl-SO_4-HCO_3 showing the maturity of the studied water (fields after Giggenbach, 1988).

3.2. Drinking Water Quality

The chemical analysis data of the water collected from the main collection tank of the Bo Traba Desalination Plant were compared to the permissible limits of WHO (2018, Table 2). Fortunately, the concentration of TDS, TH, Alk, major ions and environmentally sensitive elements in the studied water is below the permissible limits, indicating the suitability of the studied water for drinking purposes. The corrosive potential of water is determined primarily by the water's pH and total alkalinity. Water pH is the most important single term for estimating corrosively;

- If the pH is below 6.0, the water is considered highly corrosive.
- If the pH is between 6.0 and 6.9, the water is somewhat corrosive, and stagnant testing is probably appropriate.
- If the pH is between 7.0 and 7.5, the water is probably not excessively corrosive.
- If the pH is above 7.6, the water should not be particularly corrosive to metal plumbing.
- The result showed, the range of pH from 6.65 to 6.92 that indicated the studied water sample is belong, the water is somewhat corrosive (Singh, S. and Hussian, A.,2016).

Table 2: The permissible limits of WHO (2018) for drinking water (concentrations in mg/l)

Contaminant	WHO
pH	8
K	100
Ca	200
Na	200
Mg	150
Fe	0.3
Cl	250
HCO_3	600
SO_4	600
NO_3	10
TDS	500
TH	500
Alk	200
F	1.5
Br	0.5
Ba	0.005
Se	0.05
Pb	0.01
Hg	0.001
As	0.1
Cd	0.002
Cu	2
Zn	3
Cr	0.05
Ni	0.02
U	0.03

The metal index (MI) is calculated as: MI = C/MAC (where, C is the metal concentration (mg/l) and MAC (mg/l) is the permissible limit of WHO (2018)). Caerio *et al.*, (2005) classified MI into six classes: (1) Class I (very pure <0.3); (2) Class II (pure 0.3-1); (3) Class III (slightly affected 1-2); (4) Class IV (moderately affected 2-4); (5) Class V (strongly affected 4-6); and (6) Class VI (seriously affected >6). The MI values suggest that the main collection tank of the Bo Traba Desalination Plant holds pure water.

Based on the TDS concentration, Bruvold and Daniels (1990) classified water into five classes: (1) Excellent (<80 mg/l); (2) Good (80-500 mg/l); (3) Fair (500-800 mg/l); (4) Poor (800-1000 mg/l); and (5) Unacceptable (>1000 mg/l). The TDS concentration (64 mg/l, in average) indicates that the studied water belongs to the excellent class. Moreover, Sawyer and McCarthy (1967) classified water (on the basis of the TH concentration) into four classes: (1) Soft (<75 mg/l); (2) Moderately hard (75-150 mg/l); (3) Hard (150-300 mg/l); and (4) Very hard (>300 mg/l). The TH values (98.09 mg/l, in average) suggest that the studied samples is classified as moderately hard water.

4. Conclusions

The conclusions can be summarized in the following points:

The water collected from the main collection tank of the Bo Traba Desalination Plant; NE Libya is of Type II ($CaHCO_3$ Type).

2. Limestone dominance strongly affect the chemical composition of the water.
3. According to pH classification, the water samples is reflected somewhat corrosive.
4. Based on TDS categories, the water samples is characterized by moderately hard water.
5. The heavy metals in the studied water are in the permissible limit.

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