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Evaluating the quality of desalinated ground water using reverse osmosis techniques: A case study of Tobruk city. Libya

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Abstract
The city of Tobruk is located within the libya country, a semi-arid area with a fragile environment, characterized by poor soil, the absence of surface water, and scarce rainfall. the salinity of most groundwater reservoirs in the study area is high, ranging from 1620 to 3656 mg/L, making the water unsuitable for human use. The main objective was to evaluate the quality of groundwater desalinated by reverse osmosis plants. The results were then assessed using criteria established by the World Health Organization standards (WHO) and the National Center for Standards and Measurements of Libya, located at the Tajoura Industrial Research Center. Four groundwater wells were selected in different areas and samples were taken from each well before and after the desalination process. The results showed pH before the desalination process of 8 to 8.2and after the desalination process of 8 to 7.4 and an electrical conductivity ranging before the desalination process of 8060 µscm-1to 17350 µscm-1and after the desalination process of 363 µscm-1to 1200 µscm-1. Total dissolved solids (TDS) levels ranged before the desalination process from 4030 mg/l to 8800 mg/l after the desalination process of 182 mg/l to 601 mg/l . The amounts of the anions identified as nitrate, sulfate, and chloride ranged before the desalination process from 0 mg/l to 245 mg/l , 0 mg/l to 1200 mg/l, 1917 mg/l to 3550 mg/l respectively. The amounts of the anions identified as nitrate, sulfate, and chloride ranged after the desalination process from 0 mg/l to 300 mg/l , 0 mg/l to 200 mg/l , 36 mg/l to 335 mg/l respectively. The concentrations of magnesium, iron, and calcium before the desalination process that varied between 0 mg/l to 820 mg/l , 0 mg/l to 0.03 mg/l , 1917 mg/l to 3550 mg/l respectively. The concentrations of magnesium, iron, and calcium after the desalination process that varied between 0 mg/l to 250 mg/l , 0 mg/l to 0.1 mg/l , 36 mg/l to 335 mg/l respectively. The results revealed that the majority of the groundwater samples desalinated by the reverse osmosis process were within the range specified by the World Health Organization and the National Center for Standards and Measurements of Libya, located at the Tajoura Industrial Research Center.
KEYWORDS: *Groundwater, Quality, Reverse Osmosis, Desalination.*

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I. Introduction

Water serves as the foundation of life, essential for human survival, and is a critical resource for ensuring the sustainable economic development of a nation. As the global population continues to rise, the disparity between water supply and demand is expanding, reaching concerning levels that threaten human existence in certain regions of the world[1].The increasing scarcity of freshwater is a significant global issue ,as merely 1% of the Earth's water is accessible for human consumption[2].

Globally, groundwater plays an essential role in advancing the fulfillment of the human right to water. In the context of developing countries, approximately 2.1 billion individuals still do not have access to safely managed water, while 844 million lack even the most basic water services[3]. The advancement of groundwater resources is regarded as a crucial approach to bridging deficiencies in service provision[4] . Resilience to the effects of climate change is essential. Groundwater has become the primary source of drinking water worldwide[5]. The overall economic advantages of extracting groundwater surpass those associated with surface water on a per unit volume basis . Groundwater typically flows at a gradual pace, with velocities ranging from 0.01 to 10 meters per day under natural circumstances. The duration for which groundwater remains in storage, known as residence time, can vary significantly, spanning from several decades to thousands of years[6].

II. General Concept in Membrane Process

Either electrically or pressure-driven technologies are typically used in membrane treatment procedures. The four overlapping categories of pressure-driven membrane operation are microfiltration (MF), ultra filtration (UF), nanofiltration (NF), and reverse osmosis (RO). Reverse osmosis and, to a lesser degree, nanofiltration are thought to be efficient methods for removing salt[7,8]. Membrane-based wastewater treatment is expanding steadily, with estimates for growth up to 2010 exceeding 15% annually. Though MF and RO are the most prevalent membrane types in this field, practically all membrane types are used in waste water treatment and water reuse [9].Membrane distillation (MD) is thought to have the most promise among desalination technologies because it requires little energy, operates at low pressure and temperature, and is less expensive than traditional methods like distillation and reverse osmosis (RO)[10,11].

III. Reverse osmosis Process: Basic Principle

Reverse osmosis (RO) is a physical process that leverages the phenomenon of osmosis, specifically utilizing the difference in osmotic pressure between saline water and pure water to effectively eliminate salts from the water[7]. Reverse osmosis (RO) is a membrane process that operates under pressure, wherein a feed stream is forced through a semi permeable membrane. This process effectively separates two aqueous streams: one that is high in salt concentration and another that is low in salt concentration. When the pressure applied exceeds the osmotic pressure ,water is able to pass through the membrane, while the salt is retained. Consequently, this results in the production of a permeate stream with low salt concentration, while concentrated brine is left on the feed side[12]. The pretreatment system, high-pressure pump, membrane module, and post treatment system are the four main subsystems that make up a typical RO system. The pretreated feed water is pushed across the membrane surface by means of a high-pressure pump. For brackish water, RO operating pressure is between17and 27 bars, while for sea water ,it is between 55 and 82 bars[13]. Because brackish ground water has lower osmotic pressure than Seawater ,it takes a lot less energy to desalinate .Additionally, the brackish-water RO system's lower pressures allow for the use of in expensive plastic parts[14].

IV. Methodology and Research Methods

4.1 Defining the study area

The city of Tobruk is located in the northeastern part of Libya, situated on the Al- Batnan plateau, with an elevation ranging from 150 to 250 meters above sea level. Its importance stems from the presence of its naturally protected harbor, and it serves as a key station along the main coastal road between Derna and the Egyptian border, covering a distance of 340 kilometers. Tobruk is located approximately in the middle of this distance, and it also marks the starting point for the road extending from the coast to the city of Ajdabiya. Geographically, the study area extends from the Krom Al-Khail area in the west to the center of the city in the east, and from the sea in the north to the memorial of the martyrs of the Battle of Al-Nadoura in the south. A large part of the city is shaped like a peninsula (Figure 1 shows the study area). Astronomically, the study area is located at the intersection of longitude 27°58'23" East and latitude 32°5'46" North. This positioning shows that the area lies about 8 degrees north of the Tropic of Cancer. The study area, with its semi-desert climate, faces the same challenges as other parts of the country, including the scarcity of water suitable for use and the increasing demand for water. Therefore, this study highlights various aspects of this problem.

Figure1: Illustrates the study area.

4.2 Sample preparation method

Eight (8) groundwater samples were randomly collected before and after the treatment process in sealed plastic containers to prevent any changes in some of the chemical and physical properties. The sample collection took place during January 2025, and they were immediately transported to the laboratory at the Arabian Gulf Oil Company for conducting all the required tests. Table 1. shows the key data and sizes of these samples used in the study, while Figure 2. displays images of the samples analyzed in the study.

Table1: Data for the Selected Groundwater Samples for the Study

No	Sample Name	Process	Sample Code	Sample Quantity	Sample Location
1	Groundwater	Before desalination	A	1 liter	Al-Andalus District
2	Groundwater	After desalination	B	1 liter	Al-Andalus District
3	Groundwater	Before desalination	C	1 liter	Al-Manara District
4	Groundwater	After desalination	D	1 liter	Al-Manara District
5	Groundwater	Before desalination	E	1 liter	Al-Hadaeq District
6	Groundwater	After desalination	F	1 liter	Al-Hadaeq District
7	Groundwater	Before desalination	G	1 liter	Al-Tahkeem District
8	Groundwater	After desalination	H	1 liter	Al-Tahkeem District

Figure .2:Shows images of the samples analyzed in the study

4.3 Tests, devices used ,and analysis method

All standard methods employed in this study were based on the guidelines of the National Center for Standards and Measurements of Libya, located at the Tajoura Industrial Research Center. The results of all analyses were compared with the international and local standards set by the World Health Organization (WHO) for conducting chemical and physical analyses. Consequently, all tests for this study were carried out in the laboratories of the Chemical and Physical laboratories Department att he Arabian Gulf Oil Company. Table 2,presents data for all chemical elements, values, and permissible ideal ratios according to local and international standards.

Table 2:Data for All Chemical Elements Based on Local and International Standards(WHO 1998)

No	Che & phy analysis	Units	Approved Standard Specifications	
			Local Standard Specifications	International Standard Specifications
1	pH	/	8.5–6.5	8.5–6.5
2	T.D.S	mg/l	1000-500	800-500
3	EC	Ms/cm	-	1500-450
4	Ca	mg/l	75	200–30
5	Mg	mg/l	30	50–10
6	C1	mg/l	250	600-200
7	F	mg/l	1	1.50 -0.80
8	S_{O4}^{-2}	mg/l	250	400- 200
9	N_{O3}^{-2}	mg/l	10	45–10
10	Fe^{+2}	mg/l	0.30	0.30

4.4 Physical properties analyses

Among the most important physical analyses for evaluating water quality are the analysis of pH, electrical conductivity, and total dissolved salts in the samples. The physical properties of the samples were measured using the sample measuring devices, as shown in Table 3.

4.5 Chemical analyses

Chemical elements, particularly heavy metals, are crucial in water samples. The chemical properties of the samples were measured using the measuring devices listed in Table 3. The results were compared with local and international specifications.

Table3: Tests, Devices Used, and Permissible Values

No	Experiment lab	Devices uses	Approved Standard Specifications
1.	pH	Water proof meter	8.5–6.5
2.	T.D.S	Water proof meter	mg/l500
3.	EC	Water proof meter	1200-500
4.	Ca	Titratewith0.1EDTASolution	mg/l75
5.	Mg	DR6000-Spectrophotometer/Hach lange	mg/l30
6.	C1	Titratewith0.1Silver Solution	mg/l250
7.	S_{O4}^{-2}	Hach lange/DR6000- Spectrophotometer	mg/l250
8.	N_{O3}^{-2}	Hach lange/DR6000- Spectrophotometer	mg/l45
9.	Fe^{+2}	Hach lange/DR6000- Spectrophotometer	mg/l0.30

V. Results and discussion

5.1 Results of physical property analyses:

According to the results obtained from the analyses ,which are summarized in the following table:

Table 4: Results of Physical Property Analyses for the Study Area

No	Sample Code	Comparison of the Approved Standard Specifications for the Variables with the Analysis Results Before and After the Desalination Process			
		Inter Stand	6.5 – 8.5	500- 800 mg/l	1500-450
		Local Stand	6.5 – 8.5	500 - 1000	<500-1200
		PH		TDS	EC
1	A	8		8800	17350
2	B	8		420	839

3	C	8	6870	13550
4	D	8	310	620
5	E	8	6330	12620
6	F	7	182	363
7	G	8.2	4030	8060
8	H	7.4	601	1200

5.1.1 pH results before and after desalination process

Figure 3: The results demonstrate that the groundwater samples meet the World Health Organization standards (WHO) and the National Center for Standards and Measurements of Libya requirement for water quality The results showed pH before the desalination process of 8 to 8.2and after the desalination process of 8 to 7.4

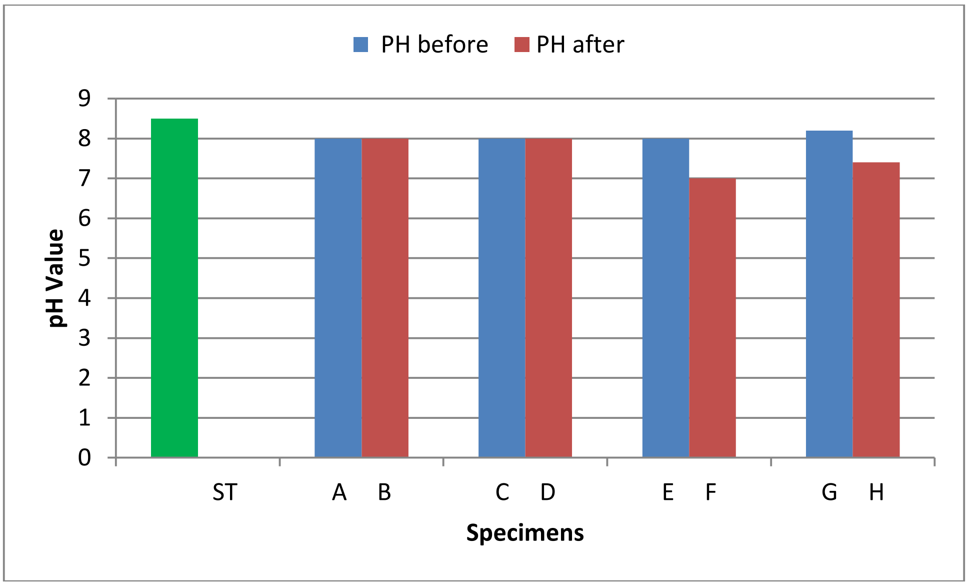

Figure 3: pH analysis comparison

5.1.2 Total dissolved solids (TDS) before and after desalination

Figure 4: shows the Total Dissolved Solids (TDS) before the desalination process for the samples studied, Total dissolved solids (TDS) levels ranged before the desalination process from 4030 mg/l to 8800 mg/l after the desalination process of 182 mg/l to 601 mg/l.

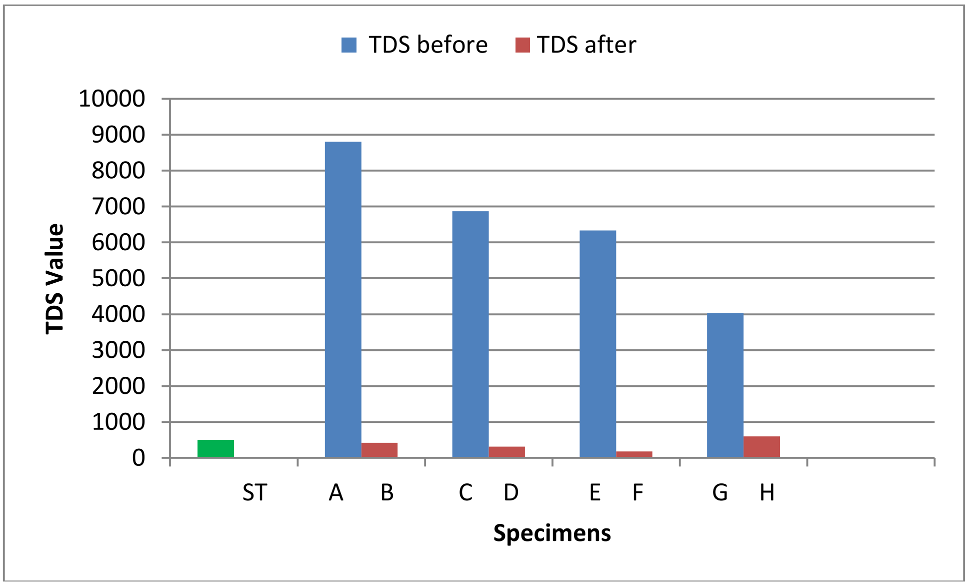

Figure 4: TDS analysis comparison

5.1.3 Electrical conductivity before and after desalination

Figure 5: demonstrates the electrical conductivity before the desalination process for the samples studied, where the values were ranging before the desalination process of 8060 µscm^{-1}to 17350 µscm-^{1}and after the desalination process of 363 µscm^{-1}to 1200 µscm^{-1} .

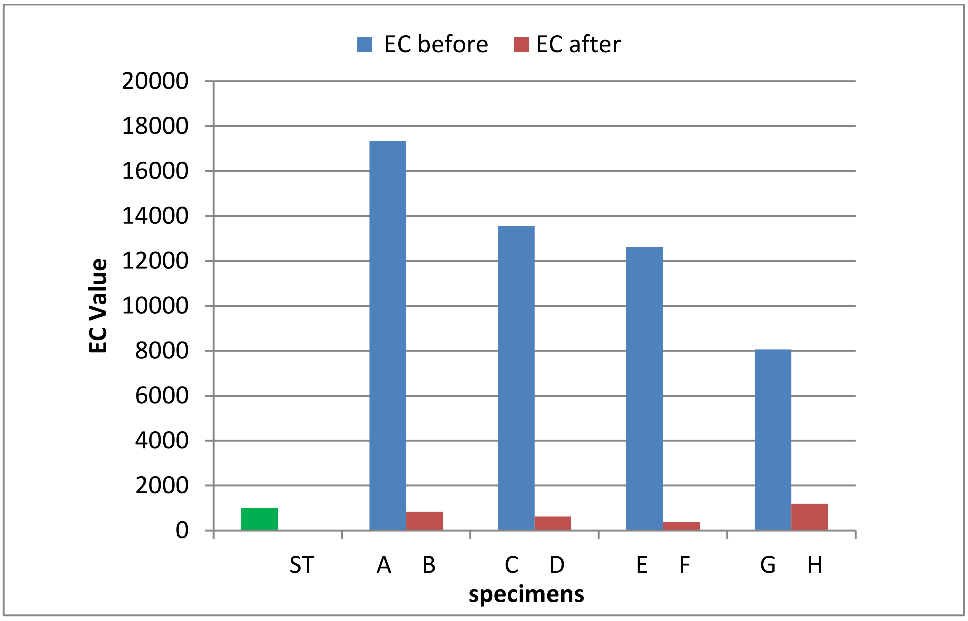

Figure 5: EC analysis comparison

5.2 Results of chemical analyses

Table 4:presents the results of chemical analyses of the variables for the study area.

No	Sample Code	Comparison of the approved standard specifications for the variables with the analysis results before and after the desalination process					
		<250 (mg/l)	<0.3 (mg/l)	<200 (mg/l)	45 (mg/l)	30 (mg/l)	75 (mg/l)
		C1	Fe	So_4^{-2}	N_{O3}^{-2}	Mg	Ca
1.	A	3550	0.02	1200	275	513	1280
2.	B	107	0.08	100	285	0	0
3.	C	2130	0.03	1150	265	424	1060
4.	D	107	0.1	50	300	32	80
5.	E	2050	0.02	950	245	0	1350
6.	F	36	0	200	230	0	0
7.	G	1917	0	0	0	820	170
8.	H	335	0	0	0	250	100

5.2.1 Calcium levels before and after desalination

Figure 6: Calcium content before the desalination process in the sampled area shows a range between 170 mg/l to 1350 mg/l and after the desalination process shows a range between 0 mg/l to 100 mg/l .

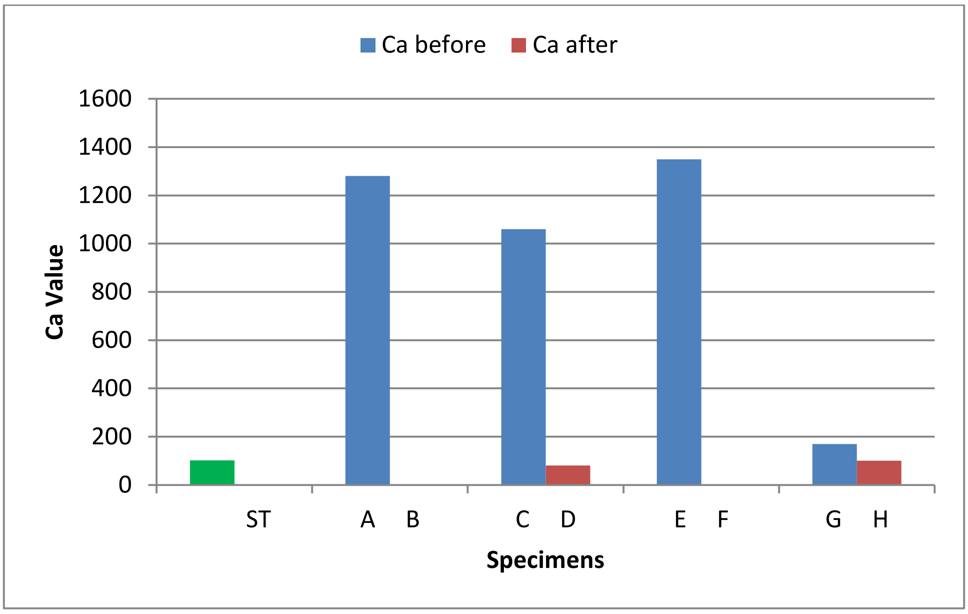

Figure 6:Calcium analysis comparison

5.2.2 Magnesium levels before and after desalination

Figure 7: shows the magnesium levels before the desalination process for the samples studied range between 0 mg/l to 820 mg/l and after the desalination process shows a range between 0 mg/l to 250 mg/l.

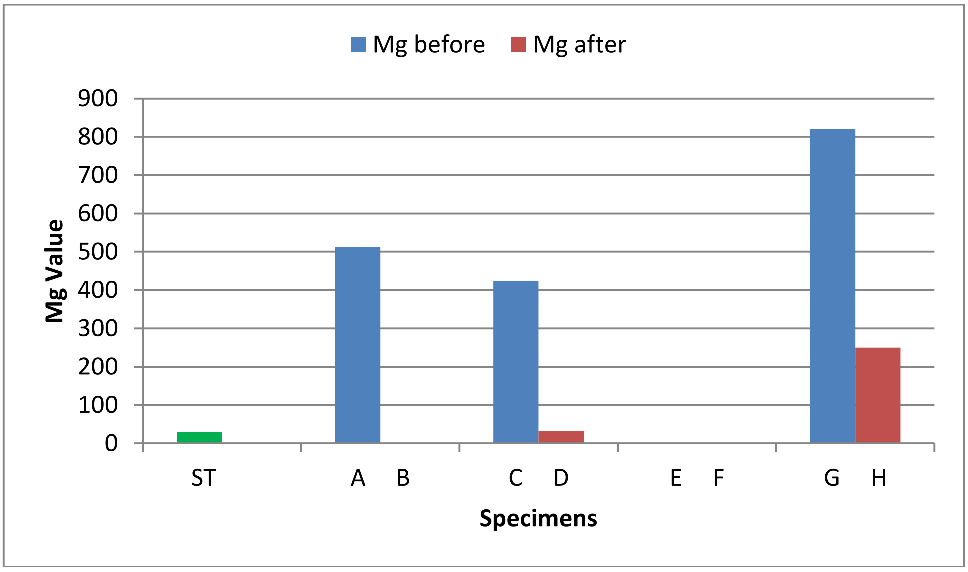

Figure 7 :Magnesium analysis comparison

5.2.3 Chloride levels before and after desalination

Figure 8: The concentration of chloride in the area of interest before the desalination process ranged from 1917 mg/l to 3550 mg/l and after the desalination process shows a range between 36 mg/l to 335 mg/l.

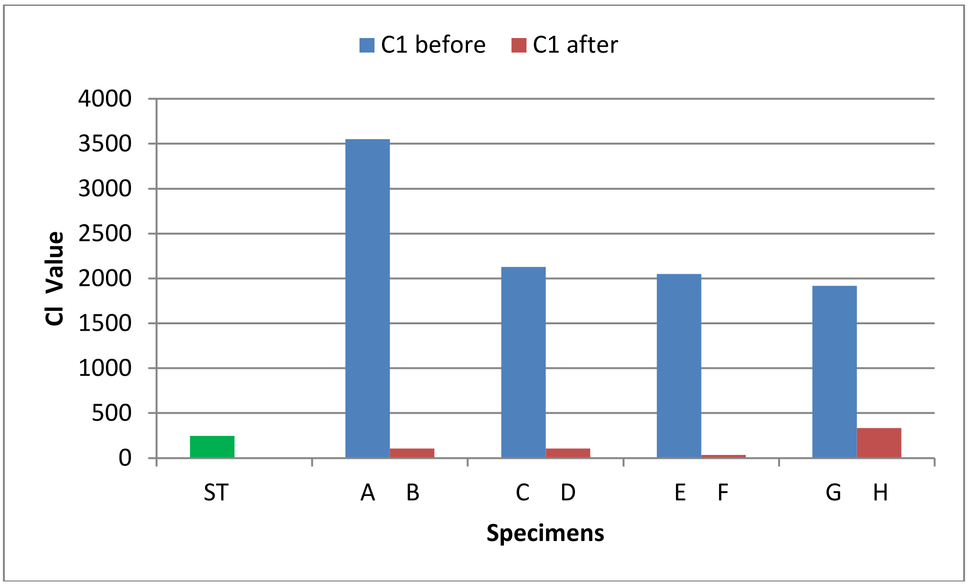

Figure 8:Chloride analysis comparison

5.2.4 Sulfate levels before and after desalination

Figure 9: The concentration of Sulfate in the area of interest before the desalination process ranged from 0 mg/l to 1200 mg/l and after the desalination process shows a range between 0 mg/l to 200 mg/l.

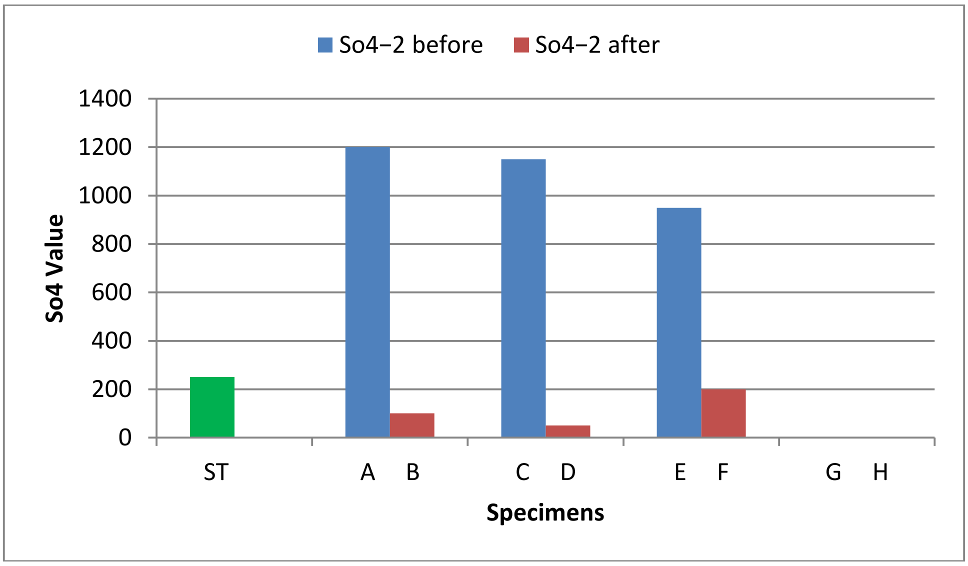

Figure 9:Sulfate analysis comparison

5.2.5 Nitrate levels before and after desalination

Figure 10: Nitrate content in the groundwater samples from the research region before the desalination process ranged from 0 mg/l to 245 mg/l and after the desalination process shows a range between0 mg/l to 300 mg/l .

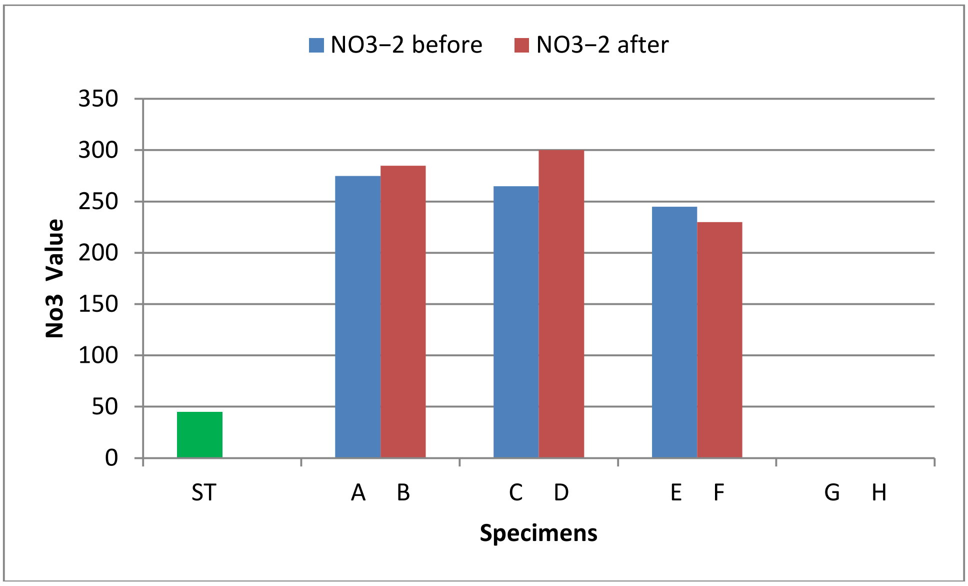

Figure10:Nitrate analysis comparison

5.2.6 Iron levels before and after desalination

Figure 11: Iron content in the groundwater samples from the research region before the desalination process ranged from 0 mg/l to 0.03 mg/l and after the desalination process shows a range between 0 mg/l to 0.1 mg/l.

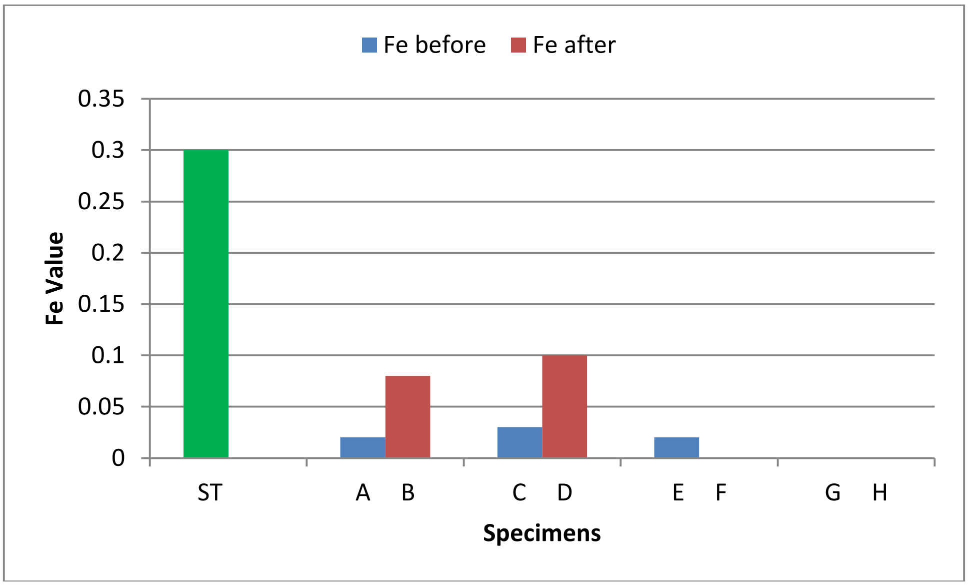

Figure11:Iron analysis comparison

VI. Conclusions

This study aimed to evaluate the quality of private groundwater desalination plants by comparing the results before and after the desalination process with local and international standards. The key conclusions are as follows:

- The results also showed that the majority of the parameters examined in the groundwater samples appeared to be within the range of the National Center for Standards and Measurements of Libya, which is housed at the Tajoura Industrial Research Center, and the World Health Organization (WHO).
- Chemical analyses indicated that after desalination, the levels of most elements were close to those specified by the World Health Organization and the Tajoura Industrial Research Center , with the exception of nitrates and iron.

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