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Quality Assessment of Underground Water before and afterTreatment: A Case Study of Tobruk City, Libya

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ABSTRACT

The present study was carried out to assess the quality of various wells for drinking purposes and with regard to their current state of repair. Ten wells (W1, W2, W3, W4, W5, W6, W7, W8, W9 and W10) were selected in the study area. This study was designed to determine the physico-chemical and bacteriological quality of wells water before and after water treatment in east Libya, specifically in Tobruk. The bacterial load (E. Coli) of the water samples was determined using standard microbiological methods. Physicochemical properties including pH, total dissolved solids (TDS), electrical conductivity, and Na^+, K^+, Ca^{2+}, Cl^-, NaCl concentrations and total alkalinity were determined. The values obtained were compared with the World Health Organization (WHO) standards for drinking water. The results showed that E. Coli bacteria were present in some wells prior to treatment, but were *E. Coli*-free post-treatment. Furthermore, the physico-chemical parameters of the water samples were generally greater the limits recommended by the WHO with particularly high values seen in well W10, prior to treatment. However, only a few of the bacteriological and physicochemical parameters of the water samples remained above the tolerable limits recommended by the WHO (WHO, 2011) post-treatment. This suggests that regular monitoring and purification of boreholes to ensure good water quality is vital to maintaining the required health standards.

1 Introduction

The increase in the number of people who are today using underground water for different forms of human activity, such as freshwater, agriculture, industry, and other uses. In Libya, groundwater from wells represents the major sources of drinking water and water for domestic purposes (Salem & Alshergawi, 2013). Polluted water is main cause of diarrhoea worldwide (UNICEF, 2013) and this report showing that 2,000 children under 5 years old die every day all world due to diarrheal diseases, 90% of which are directly related to contaminated drinking water. Aquifers are a huge storehouse of Earth's water which is estimated to be about 94% of fresh water and people all over the world depend on groundwater in their daily lives (Heath, 1987). The cycle of groundwater begins with water falling on the land surface and slowly penetrating deep into the earth. Before reaching the ground, however, the rain comes into contact with bacteria and some of dissolved solids and suspended solids (Gibb, 1973). The source of diseases due to micro-organism and pollution related to drinking water from wells by non-suitable means used in treatment plants (Al-Azzawi, 2010). For this reason, the WHO has identified lack of access to clean drinking water as the most critical factor influencing the general health and wellbeing of populations in developing countries

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(Hoko, 2005). Overall, the provision of safe drinking water can help to reduce or eliminate preventable deaths (such as those emanating from waterborne diseases) and improve the quality of life for low-income households around the world (Lawson & Emmanuel, 2011). The main objective of this study is to evaluate the quality of borehole water in different communities in selected districts of Tobruk, Libya, and its nearby surrounding for drinking purposes. This study is considered to be the first of its kind to assess groundwater quality in this region. Therefore, this study will be an essential reference for decision makers with regard to regional groundwater management and protection.

1.1 The Geomorphology of the City:

The north-eastern coastal area of Libya is subdivided into two geomorphic units; the northern scarped terrain (Al Dafna plateau), which is marked by the presence of many prominent scarps running in an ESE-WNW direction and the southern part of Al Bardia area, which is flat and monotonous plain (El Deftar, 1977; Sweedan, 1977). Stratigraphically, the Al Dafna coastal plateau is formed of Late Eocene to Early-Middle Miocene succession and is subdivided into three formations: (i) the Al Khowaymat Formation (Late Eocene-Early Oligocene), which is considered to be the oldest rock unit in the region and that consists of limestone and dolomite. Glauconitic and Nummulite layers occur at the top of the section; (ii) the Al Faidiyah Formation: (Late Oligocene-Early Miocene), which consists of chalky limestone layers rich with fossils and carbonate mud. It constitutes 90% of the rocks that appear on the beach in the eastern region, starting from the city of Darnah, forming cliffs, terraces and sea heads; and (iii) the Al Jaghbub Formation (Early-Middle Miocene), which is a hard limestone with a yellowish-white colour but

that can also be reddish in some parts and that covers most of Tobruk. Al Jaghbub Formation layers are the most widespread and distributed in the areas of the study with thicknesses reaching up to 34.5 metres (Adam, 2018).

1.2 The study area:

The study area lies in Tobruk, located in eastern Libya. It lies at latitude 32^0 04` 45" N and longitude $23^0$ 57` 20" E on the Mediterranean Sea coast of the eastern part of Libya. Comprising the east of the city at W1 Almnara Street, W2 Abdulmnam Ruad Area, W3 Aldaman Building, W4 Almokthar street, W5 Alnaser area, W6 Wadi Rasbuad, W7 Bab Elzuton area, W8 Alros area, W9 Akrom Alkhail (1), and W10 Akrom Alkhail (2), with the locations of underground water wells displayed in Fig. 1.

2 Materials and Methods:

2.1 Collection of Samples:

During two trips in the same month, Dec. 2020, twenty samples were collected from ten stations, with one sample from bottom of each well and the other from the surface after water treatment in all wells. The pHs were measured in situ using a portable pH because the parameters are likely to change during transport. **Fig. 2** shows the locations of the wells from which the water samples were collected at different locations in the Tobruk city area

2.2 Micro-analysis

The powder (Mac Conkey Agar) 49.5g was dissolved in 1L distilled water with swirling the water. The autoclave was running at 120°C for one minute, after cooling to room temperature, 1 ml of the sample was added and the sample was then left to grow for 84 hours in the lab at room temperature.

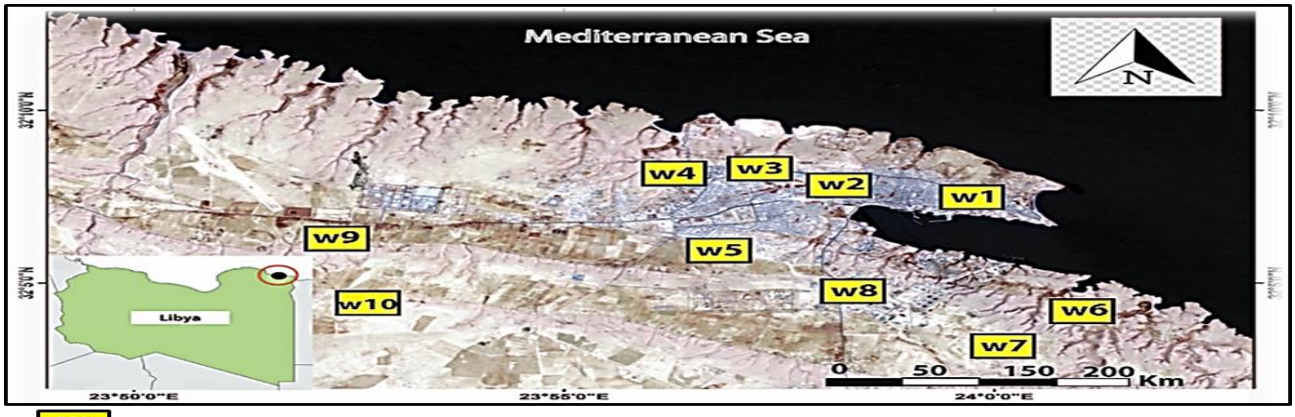

Fig. 1. Location of study area and groundwater samples.

Fig. 2. A and B are sample collections from Amanara Street prior to the treatment process. Pictures C and G show water samples being taken directly after treatment of the water, and pictures D and F illustrate water collections from Abd El mnam ruad station E, measuring Ph at the same time at Abd El mnam ruad station H.

2.3 physicochemical analysis

The various results obtained for the physicochemical analysis of the water samples from the various wells are presented in **Figs 3-9** and their data reported in **Table 2** in discussion section. pH was determined in this study using an "Inolab pH meter 720" which was equipped with a temperature compensating device. The instrument was calibrated using standard pH buffers (pH 4, 7, and 10) and the TDS of water samples. The TDS was determined using a "T.G.W" TDS meter. The instrument was calibrated using standard TDS buffers (1000 mg/L). Conductivity of water samples .The conductivity in µS/cm was determined by "Milwaukee". The instrument was calibrated using a standard conductivity buffer (4000 µS/cm), with sodium and potassium levels in water samples determined using a CARELYTE electrolyte analyser. A standard solution was prepared by dissolving 0.7915g KCl and 0.4715g NaCl in 1 L distilled water to produce a solution of 500 ppm K and 250 ppm Na. This solution was used as a stock solution and diluted to prepare the standard solutions used in the analysis. By plotting a graph of display readings against standards concentrations, and then taking a reading from the sample, the concentration of sodium

and potassium in the sample can be calculated from the calibration plot (Shibata Y, 1992). The chloride ion concentrations in the water samples were determined via titration of 10 mL water sample and 5 mL K_2CrO_4 (3.5 g potassium chromate in 1 L distilled water) against silver nitrate solution (3.7 g silver nitrate in 100 mL distilled water). The titration was performed until the colour of the solution changed to orange (Gaith G. A Jalgaif et al., 2018).

3 Results

3.1 Micro-analysis

Twenty water samples was taken on the same day and transferred directly to the Al-Aman Laboratory for chemical analysis within two hours for analysis at ambient temperature. **Table 1** shows that *E. coli* were present in most of the samples except for the water samples from wells W1, W7, and W10. The

corresponding results will be discussed in more detail in the dissection section.

Table 1. The *E. coli* detection in the samples.

Well Code	Sample No.	Microbiological Test	Result
W1	A*	Negative	-
	A**	Negative	-
W2	B*	Positive	*E. Coli* (+Ve)
	B**	Negative	-
W3	C*	Positive	*E. Coli* (+Ve)
	C**	Negative	-
W4	D*	Positive	*E. Coli* (++Ve)
	D**	Negative	-
W5	E*	Positive	*E. Coli* (+++Ve)
	E**	Negative	-
W4	D*	Positive	*E. Coli* (++Ve)
	D**	Negative	-
W5	E*	Positive	*E. Coli* (+++Ve)
	E**	Negative	-
W6	F*	Positive	*E. Coli* (+Ve)
	F**	Negative	-
W7	J*	Negative	-
	J**	Negative	-
W8	H*	Positive	*E. Coli* (+Ve)
	H**	Negative	-
W9	G*	Positive	*E. Coli* (+Ve)
	G**	Negative	-
W10	K*	Negative	-
	K**	Negative	-

Where: "*" and "**" are the number of samples before and after treatment, respectively.

3.2 Physicochemical analysis

3.2.1 5.2.1 pH

pH is an important parameter, which represents the degree of ionization of the medium studied; in this particular instance, it gives an indication on the level of the pollution of the water. The pHs of the samples before treatment range from 6.9 to 7.7, with an average of 7.30; after treatment, it ranged from 6.1 to 7.4 with an average of 6.5, as illustrated in Fig. 3 and Table 2.

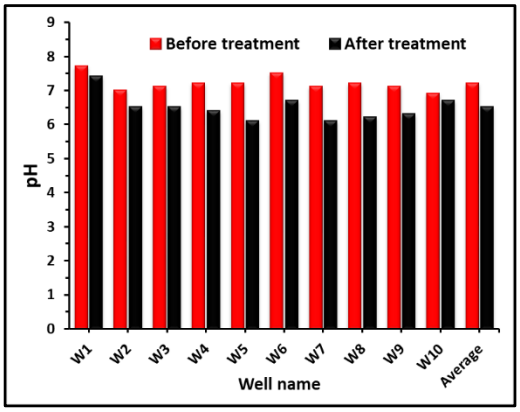

Fig. 3. Bar graph distribution for pH concentrations.

3.2.2 Total dissolved solids, TDS

TDSs are illustrated in Fig. 4. Their values before treatment fluctuated between 2850 and 14,640 mg/L, with an average of 6667 mg/L. The highest TDS value was recorded for W10. However, the TDS content after treatment was found to vary from 500 to 3300 mg/L, with an average of 1840 mg/L, and for which the highest TDS content was recorded for W8.

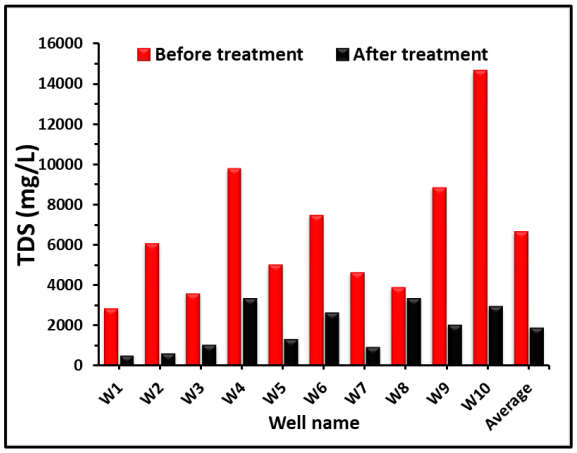

Fig. 4: Bar graph distribution for Total dissolved solids TDS concentrations.

3.2.3 Sodium ions, Na^+

The data obtained for sodium ion concentrations are given in Fig. 5. The results show that the Na concentrations prior to treatment varied from 1112 to 3556 mg/L, with an average 1937.2 mg/L, with the highest concentration recorded for W10, while after treatment it varied from 131.7 to 196.4 mg/L, with an average 161.39 mg/L and the highest concentration at W8.

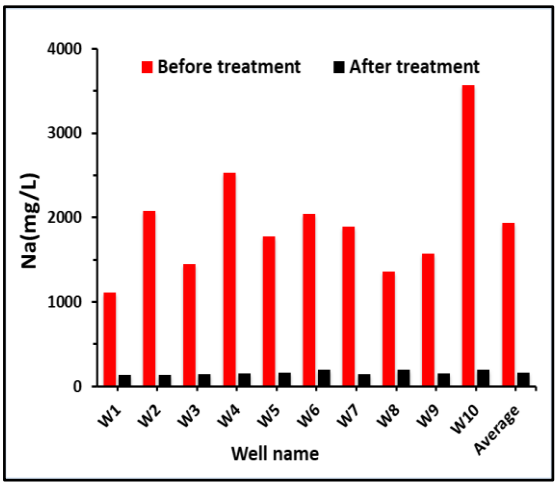

Fig. 5. Fig. 5. Bar graph distribution for sodium ion concentrations

3.2.4 Potassium ion, K^+

The distribution of potassium ion concentrations is shown in **Fig. 6**. This fluctuates between 108 to 22 mg/L prior to treatment, with an average of 54.9 mg/L. The highest K concentration of 108 ppm was recorded at Station 10. Akrom Alkhail (2). By contrast, K concentrations after treatment in the area of study ranged from 3.2 to 9.6 mg/L, with an average of 5.27 mg/L, with the highest concentration found at Station 4 (Almokthar Street).

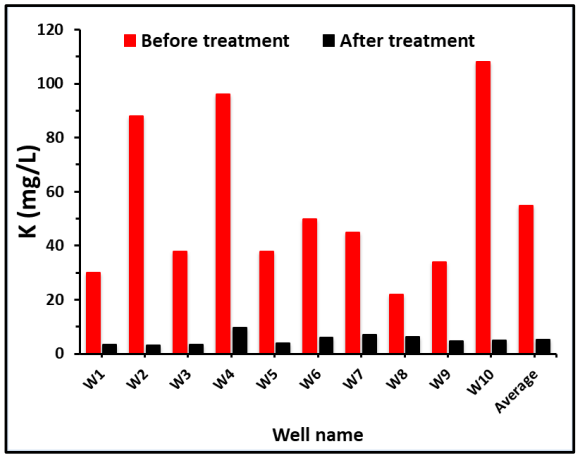

Fig. 6. Bar graph distribution for potassium concentrations.

3.2.5 Calcium ions, Ca^{2+}

Calcium ion concentrations are illustrated in Fig. 7. Prior to treatment, Ca^{2+} concentrations were found to vary from 400 to 1100 mg/L, with an average 809.4 mg/L. The highest concentration was seen at W10. After treatment, Ca^{2+} concentrations were found to range from 83.6 to 22 mg/L with an average of 56.95 mg/L, with stations W1, W2, W3, and W9 showing recorded values lower than the WHO permissible limits (WHO, 2011).

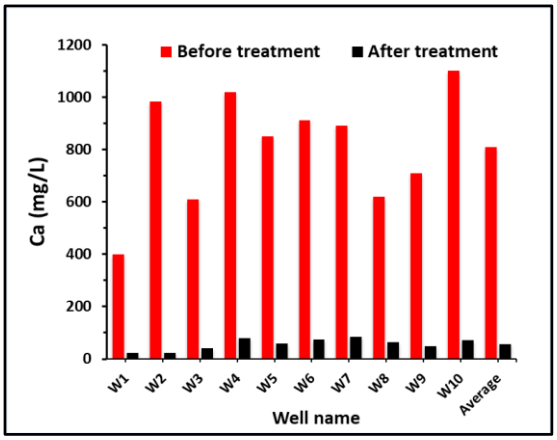

Fig. 7. Bar graph distribution for calcium ion concentrations.

3.2.6 Chloride ions, Cl^-

Chloride concentrations before treatment in the study area, as illustrated in **Fig. 8**, varied between 3130 and 6680 mg/L with an average of 4559.5 mg/L. On the other hand, after water treatment, Cl^- concentrations varied between 710 and 1065 mg/L, with an average of 710 mg/L.

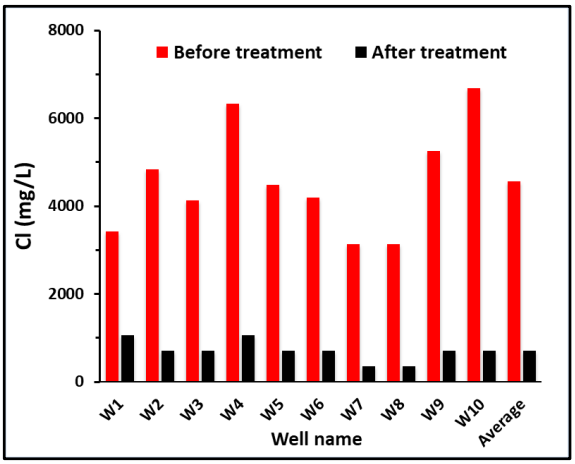

Fig. 8. Bar graph distribution for chloride ion concentrations**.**

3.2.7 Sodium chloride, NaCl

The data for sodium chloride concentrations are given in Fig. 9. The result before treatment showed that NaCl content ranged between 3940 and 9360

mg/L, with an average of 5964.5 mg/L, with the largest concentration recorded at Station 10. However, NaCl values after treatment were found to vary between 585 to 1755 mg/L, with an average of 1170 mg/L. Notably, the higher levels of NaCl concentrations were determined in five wells (W2, W3, W5, W9 and W10) than in compared to the other wells with the highest value of 1170 mg/L which are the same in five wells mentioned earlier.

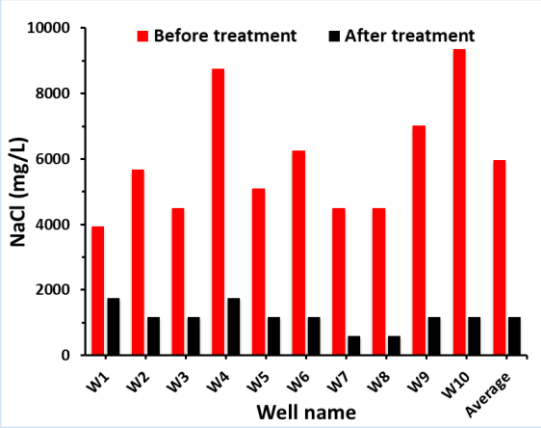

Fig. 9. Bar graph distribution for sodium chloride concentrations**.**

3.2.8. Electrical conductivity, E.C.

The conductivity of an electrolytic samples depends on its concentration were measured as shown Fig. 10 and their associated data are shown in Table 2. As expected prior to treatment of water the EC values ranged between 5.75 to 19.8 µS/Cm with an average of 12.148 µS/Cm which is considerably higher than permissible limit (1400 µmhos.cm^{-1}). It is possibly reflecting the water contains high levels of TDS because of naturally occurring elements and processes.

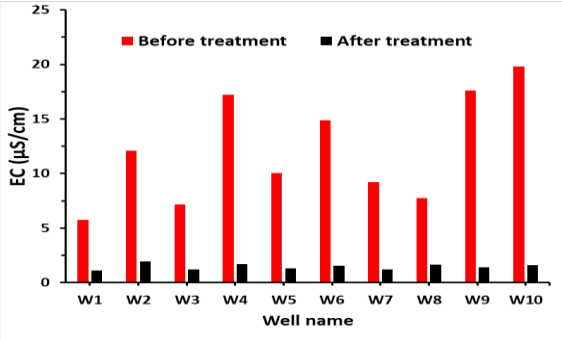

Fig.10. Bar graph distribution for EC concentrations

4 Dissection

4.1 Micro-analysis

As can be observed from **Table 1**, prior to treatment all of the water samples tested positive for *E. coli* except for the water samples from W1, W7 and W10(2), whereas after treatment none of the wells tested positive. It is worth noting that the presence of *E. coli* in all the water sources indicate that they are not fit for human consumption without prior and adequate treatment. Several health risks have been associated with the consumption of water contaminated with faecal matter; indeed, this problem is exacerbated in children under the age of 5 and immuno-compromised adults (Diouf et al., 2014; Edokpayi, 2018; Joshua et al., 2018).

4.2 6.2 Chemical analysis

Acomparison of the physico-chemical characteristics of the studied water samples of drinking water wells has been made prior and after treatment and their data reported in Table 2, collected data revealed that there were considerable variations in physico - chemical properties of examined samples from the different localities and these properties will be discussed in detail below. As shown in Fig. 3 and Table 2, the pHs of the groundwater for all wells prior to treatment were within the range of 6.9 - 7.7 with a mean of 7.30, while after treatment were within the range of 6.1 to .7.4 with the mean of 6.75, indicating that the groundwater in the study area was initially slightly alkaline for most of the groundwater samples. Notably, all the samples tested in our study fell within limits of 6.5 to 8.5 required by the WHO's quality standards for groundwater (WHO, 2011).

The concentrations of TDS before and after treatment processes ranged from 2850 to 14,640 mg/L and 500 to 3,300 mg/L, with averages of 10,170 and 1900 mg/L, respectively Fig. 4 and Table 2,. This indicates that the quality of all groundwater in the study area could be classified as very hard water to TDS (Mohamed et al., 2018; Sawyer & McCarty, 1967; Todd, 1980). In this study, the concentrations of TDS are found above the WHO-allowable limit (WHO, 2011) for Libya 1000 ppm. Initially, the Na^+ concentration was determined to be between 1112 and 2532 mg/L with an average of 1937.2 mg/L, which was higher than WHO-permissible limits (Fig. 5 and Table 2). Although higher sodium levels do not pose a serious threat to human health, they create a risk to people on low sodium diets, as usually recommended for individuals with hypertension and congestive heart failure. However, low levels of Na^+ were determined after treatment of water between of 131.7-196.1 mg/L with

an average of 161.39 mg/L, which is well below the WHO-permissible limit (WHO, 2011) for Libya, of 200 ppm. The average concentrations of untreated water, the K^+, Ca^{2+}, Cl^- and NaCl were 5964.5, 4559.5, 809.4, and 54.9 mg/L, respectively, with an average of 5.27, 56.95, 710, and 1170 mg/L, respectively 108, 1100, 6680 and 9360 mg/L, respectively see Figures 6-9 and Table 2. After treatment, the concentrations of K^+, Ca^{2+}, Cl^-, and NaCl in the groundwater were 3.3–9.6, 22.0–83.6, 355-1065, 585–1755 mg/L, with averages of 5.27, 56.95, 710, and 1170 mg/L, respectively, and all their concentrations fall within WHO-permissible limits (WHO, 2011) for Libya at 40 ppm, 50 ppm, 250 ppm, and 250 ppm, respectively. The total alkalinity varied between 300–1100 mg/L and 200–600 mg/L for before and after treatment, respectively with a mean value of 650- 370 mg/L, respectively (Table 2).

The electrical conductivity is dependent on the concentrations, types of soluble ions, as well as the temperature of the water(Hem, 1985). In this study, the EC values before treatment ranged between 5.75 and19.8 µS/cm with a mean EC for all samples analysed of 12.14 µS/cm, which indicated a large variation in EC. High ECs were found in water samples from W10, W9 and W4 prior to treatment (Table 2). The desirable limit set for natural water as stated by the WHO (Mansour, 2013; Mudgal et al., 2009) should not exceed 1400 µmhos.cm^{-1}. However, it was observed that the conductivities of the water samples was influenced by TDS and, in general, water samples post-treatment had low electrical conductivities, and their ECs in the water samples ranged between 1.11-1.95 µS/Cm with an average of 1.46 µS/Cm, suggesting that they were all compliant with the WHO guidelines and were also safe for drinking purposes safe for drinking purposes.

Table 2. Results of the Physico-chemical properties for the Ten well samples investigated.

Well No.	Samples Test	pH	EC ms/cm	TDS	Na^+	K^+	Ca^{2+}	Cl^-	NaCl	Alkalinity
				gm/*L*						
W1	before	7.7	5.75	2850	1112	30	400	3420	3940	300
	after	7.4	1.11	500	131.7	3.3	22	1065	1755	200
W2	before	7.0	12.1	6040	2076	88	984	4840	5680	400
	after	6.5	1.95	600	134.5	3.2	23.5	710	1170	200
W3	before	7.1	7.16	3580	1444	38	610	4130	4510	500
	after	6.5	1.21	1000	147.3	3.5	41.2	710	1170	200
W4	before	7.2	17.22	9770	2532	96	1020	6325	8755	800
	after	6.4	1.67	3300	151.5	9.6	80.6	1065	1755	500
W5	before	7.2	10.02	5000	1776	38	850	4485	5095	700
	after	6.1	1.28	1300	165.6	4.0	58.2	710	1170	300
W6	before	7.5	14.87	7440	2044	50	910	4195	6265	1100
	after	6.7	1.53	2600	195.9	6.0	75.5	710	1170	500
W7	before	7.1	9.22	4630	1888	45	890	3130	4510	600
	after	6.1	1.19	900	144.8	7.0	83.6	355	585	400
W8	before	7.2	7.74	3900	1362	22	620	3130	4510	600
	after	6.2	1.66	3300	196.4	6.3	65.2	355	585	500
W9	before	7.1	17.6	8820	1572	34	710	5260	7020	800
	after	6.3	1.40	2000	150.1	4.8	48.3	710	1170	600
W10	before	6.9	19.80	14640	3566	108	1100	6680	9360	700
	after	6.7	1.58	2900	196.1	5.0	71.4	710	1170	300

5 Conclusion

The present study has provide information of underground wells in some locations in Tobruk city Libya. The data show from ten points that the microanalysis illustrate that there are three locations free from bacteria W1. W7. W10 this locations lead to good structure and a new area in the same time away from domestic sewage, while W7, W10 these locations located outside city center far away. From a water quality point of view, after treatment process most of the data for the physico-chemical parameters indicated tolerable quality

Therefore, the heavy reliance on borehole water in the study area calls for constant monitoring and design of regular purification strategies by government agencies concerned to ensure good water quality.

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Conflict of interest: The authors declare that there are no conflicts of interest.

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