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Assessment of Groundwater Quality in Shebna Region, Benghazi-Libya and Its Suitability for Drinking and Domestic Purposes

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ABSTRACT

The quality of groundwater has been assessed for its suitability for drinking and human used, at Shebna region (a region of Benghazi city), during April to May 2013. The evaluation was made to ascertain compliance with recommended standards by Libyan Standard Legislation, by caring out the physical, chemical and the microbiological analysis of 20 samples. Physical and chemical parameters including total dissolved solids (TDS), electrical conductivity (EC), cationic and anionic constituents (chloride; sulphate; nitrate; calcium; magnesium were determined by standard titrimetric and spectrophotometric methods. In addition, heavy metals (Chromium, copper, iron and zinc) were also determined using the atomic absorption spectrophotometric method. Flame photometer was used to determine the concentration of sodium and potassium. The results showed that the temperature reaches 20-24.5 C, pH ranges 7.29-8.20, EC 2510-6940 µs/cm, TDS 1147-5264 ppm, chloride 400-2960 ppm, total alkalinity 176-400 ppm, total hardness 80.1-1045 ppm, nitrate 0.42-3.89 ppm (only one sample has 66.9 ppm nitrate level), sulphate 78.5-342 ppm, sodium and potassium ions range from 95.1-709 ppm and 2.43-46.0 ppm respectively. The levels of pH, nitrate, sulphate and potassium of the samples were within the guidelines set by Libyan Standard Legislation. However, the levels of hardness, total dissolved solid, sodium and chloride, of the most samples were higher than the guidelines set by Libyan Standard Legislation.The results of the chemical toxic analysis of Shebna groundwater, indicated the heavy metals (chromium; copper; zinc and iron) are absence. As for the Bacteriological pollution, the study showed a rising in Total Count and Total Count coliform of Shebna groundwater. However, the Fecal Count Coliform and the Eschriechia coli were determined in 40% of the groundwater samples.

Keywords: *groundwater, Shebna area, physical and chemical analysis ,heavy metals analysis, microbiological analysis*.

INTRODUCTION

Groundwater is the most important source of water for human consumption in semi-arid countries [**1**]. However, Libya is considered as one of the countries which suffer from limited water resources availability. The most parts of the country are either semiarid or arid and the driest regions of the world, within year average rainfall ranging from just 10 mm to 500 mm. Just 5% of the entire area of Libya exceeds 100mm annually. Even more, the evaporation rates are also high, ranging from 1,700 mm^3 in the north to 6,000 mm^3 in the south [**2**].

Benghazi is the second largest city in Libya, after the capital, Tripoli, and Benghazi is located in the north-east of Libya, overlooking the Mediterranean coast. Benghazi has a warm climate with little rain, while, the summer season in Benghazi is hot and dry. The rainfall rate in Benghazi, is less than 268 mm^3 per year. Total population in the city of Benghazi is 1,382,688 according to the statistics of 2006 and continues to increase. Therefore, there is an increase in the needs of safe water for drinking and domestic use. For these, many population in city regions dug wells to use the groundwater in different purposes, such as drinking; domestic use; agriculture and others [**3, 4**]. Numerous studies, in the city of Benghazi (study area), were conducted for a number of regions that the residents still use water wells in a variety of purposes [**5-7**].

As the water quality data is essential for the protection of the human health, this study was assess the groundwater quality in terms of its suitability for drinking and domestic uses in one of Benghazi region called Shebna. The assessing of the quality of groundwater of Shebna region is done by monitoring the physical, chemical and biological analysis.

MATERIALS AND METHODS

Shebna (also called *Al-Auruba*) is a new region of Benghazi city, fig (1). Shebna region began appearing in 1990. It is located between longitude 20° 7` 15.98`` - 20° 7` 51.12``, and between lantitudes 32° 8` 7.55``- 32° 7` 19.70``, and covers an area of about 16,434 m^2. In Shebna region, the population resorted to digging wells to take advantage of its water for drinking, domestic use and other purposes [**8**]. The groundwater in Shebna region is taken, in most cases, from *Driven Wells*. It is the best types of wells guarantee to get pure water. These wells are more than 10 m depth. Even more, the houses in Shebna region are lacking the modern sanitation systems. In fact these houses use waste tanks.

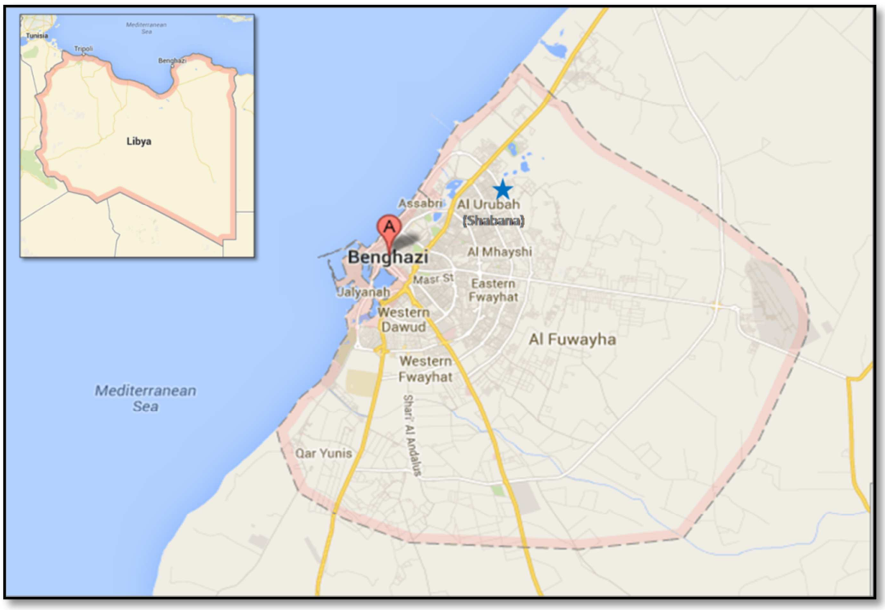

Fig (1): Map showing the location of Benghazi city and Shebna region (*)

Sampling and Analysis

The samples collecting process is adopted according to a method of random sampling from different points in the study area, which is the base most commonly used in plans for environmental studies. The coordinates of the sampling sites were identified using the device coordinates global (Global Position System-GPS) model *Mio Moov S308*, Mio Technology Ltd, china.

The groundwater samples were collected in the period from April 23, 2013 to May 23, 2013 from 20 wells of Shebna region. The information about the location of these wells (coordinates), depth, age and uses of the wells are given in table (1). Even more the distance between the groundwater well and the waste tank and the water temperature during the assembly of the sample, all of which are registered in the table (1), with a note that the samples were all colorless and odorless. The samples have collected, after 20 minutes of run-off water drawn from wells, in clean polyethylene containers of ½ liter capacity for physical, chemical analysis and the analysis of heavy elements. The samples for microbiological analysis have taken in clean glass bottles sealed and sterile, by heating them in oven at a temperature of 170°C for more than two hours after that the neck and cover of bottle rolled with aluminum foil.

The tests and measurements of water samples were conducted using standard equipments and materials, provided by the well-known international companies, in water analysis laboratories in Department of Nutrition (Faculty of Public Health, University of Benghazi and Man Made River Center (MMRC) (Hawari Region, Benghazi).

Table (1): Information on the wells of Shebna region

Sample No.	Coordination of Location						Well Depth (m)	Well Age (Year)	Distance from waste tank (m)	Uses of water
	E			N						
1	32°	07`	16.0``	20°	08`	36.6``	24	15	10	Domestic
2	32°	07`	39``	20°	07`	57.4``	26	10 months	12	Drinking& Domestic
3	32°	07`	44.0``	20°	07`	40.3``	15	13	20	Domestic
4	32°	07`	38.3``	20°	07`	02.6``	27	1.5	12	Domestic
5	32°	07`	43.0``	20°	07`	50.6``	23	8	6	Domestic
6	32°	07`	37.2``	20°	07`	40.8``	30	1.5	10	Domestic
7	32°	07`	46.4``	20°	07`	39.1``	22	2	8	Domestic
8	32°	07`	43.7``	20°	07`	30.5``	18	5	25	Drinking & Domestic
9	32°	07`	50.5``	20°	07`	45.5``	25	3	20	Domestic
10	32°	07`	50.8``	20°	08`	04.1``	30	4	10	Domestic
11	32°	07`	36.6``	20°	08`	10.2``	24	4	15	Domestic
12	32°	07`	30.8`	20°	08`	05.8``	26	5	8	Domestic
13	32°	07`	27.6``	20°	07`	58.7``	22	4	15	Drinking & Domestic
14	32°	07`	28.7``	20°	07`	50.3``	22	2	10	Domestic
15	32°	07`	38.4``	20°	07`	48.5``	27	7	15	Domestic
16	32°	07`	42.3``	20°	07`	53.9``	30	18	20	Domestic
17	32°	07`	48.8``	20°	07`	56.6``	26	20	12	Domestic
18	32°	07`	41.1``	20°	07`	55.1``	25	5	15	Domestic
19	32°	07`	32.0``	20°	07`	50.2``	23	5	5	Domestic
20	32°	07`	35.5``	20°	07`	43.9``	25	1	25	Domestic

Physical and Chemical Analysis

The temperature of the samples was measured in the field itself at the time of sample collection using mercury thermometer. Also Measurements of physical unstable parameters such as pH and electrical conductivity (EC) were conducted in the field with portable pH-meter (*Ino lab WTW*) equipped with glass combined electrode (*pH-electrode sen Tix 61-B023009AP017*) and microprocessor electrical conductive meter (*WTW Multi 340i with WTW Tera Con 325 conductive cell*) which were calibrated prior to taking of readings. The Chemical Analysis were conducted using standard procedures recommended by American Public Health Association [**9**]. Total dissolved solid was determined by gravimetric method and hardness was determined by EDTA titrimetric method. Chloride ion was determined by silver nitrate titration. Total alkalinity was determined by acid-base titration. Sulphate ion and nitrate ion contents were determined using spectrophotometric method. Analysis of sodium and potassium ions were carried out using a flame photometer (*PFP7Flame Photometer, Jenway, Germany*). The toxic heavy metals that affect the health (such as chromium, copper, iron and zinc) were determined using Atomic Absorption Spectrophotometer (V*arian SpectAA-10 plus atomic absorption spectrophotometer, Jenway, Germany*).

Microbiological Analysis

The *Total Count* (TC) of the bacteria was conducted by pour plate technique on plate count agar and counting the colonies developed after incubation at 37°C for 48 hours. *Total Coliformbacteria* (TCF) and *Faecal Coliformbacteria* (FCF) were enumerate using the Most Probable Number technique (MPN) after incubation at 37°C for 24-48 hours. The positive tubes were sub-cultured into Brilliant Green Lactose Bile Broth which incubated at 44°C for 24-48 hours, and then with Eousine Methylene Blue Agar [**10,11**].

RESULTS AND DISCUSSION

In this study, some physical, chemical parameters and microbiological analysis, for 20 samples of groundwater of Shebna region, were carried out to verify the suitability of the wells water for human uses.

Physical and Chemical Analysis

The direct measurements of pH and EC, in addition to the total dissolved solids for each sample, were conducted. Also the analysis of chloride; nitrates; sulfate; sodium and potassium ions, as well as the total hardness; total alkalinity and concentrations of some heavy elements, were performed for each sample of Shebna groundwater. The results of physico-chemical parameters of the water samples are presented in table (2) and table (3).

Temperature

The temperature values of Shebna region groundwater ranged from of 20-24.5^{0}C. A rise in temperature of water leads to the speeding up chemical reactions in water, reduces the solubility of gases and amplifies the taste and odor [**12, 13**].

Total Dissolve Solid (TDS)
TDS consists of inorganic salts and dissolved organic matter, from Table (2), the values of TDS of Shebna region samples are ranged from 1147 ppm to 5264 ppm. The Libyan Standard Legislation for drinking water states that the value of TDS of drinking water shall not be less than 500 ppm and not more than 1000 ppm [**14**]. Comparing the values of TDS of the Shebna samples with the limits set by Libyan Standard Legislation, we found the values of TDS of water samples are higher than the levels of standards recommended by the Libyan Standard Legislation. In fact all values of TDS for all samples are above 1000 ppm. The several research confirm that many of the salts present in the water should be at a moderate level, that means, the values of TDS should not be less than 500 ppm, because the human body just needs to compensate the salt lost by sweating. At the same time, the TDS in water must not exceed about 1500 ppm, which then add unpalatable salty taste. Increasing the salts may cause a damage to human kidney and undesirable physiological reactions [**15, 16**]. Water samples of Shebna region have high values of TDS may due to the nature of water or the earth around the water, or leakage of industrial or industrial sewage to natural water bodies [**14, 17**].

Electrical Conductivity
The values of EC of the water samples of Shebna region range between 2510-6940 µs/cm, table (2). The EC is considered a good measure of the proportions of the TDS in the water, i.e high EC indicates the high value of TDS in the water [**1, 16**].

PH
The pH values of the groundwater samples of Shebna region vary between 7.29- 8.20, Table (2), with an average value 7.68± 0.24 during the study period. The minimum pH value was 7.29 for sample 16, while the highest pH value was 8.20 for sample 17. However, the pH values of Shebna water samples fall within the limits permitted by the Libyan Standard Legislation for drinking water [**14**]. Generally, the pH of groundwater is influenced by geology of catchment area and buffering capacity of water.

Total Alkalinity
The term total alkalinity gives a quick indication of salts present in water sample, the main source of these salts are the surrounding soil. It was found that the limit allowed by the World Health Organization (WHO) for total alkalinity in drinking water is 120 ppm [**13**]. By comparing this value with the values of total alkalinity of Shebna region samples, which range between 176-400 ppm (Table (3)), we find the values of total alkalinity for all samples were higher than the limit allowed by the WHO [13].

Table (2): Physical Parameters of groundwater of Shebna Region

Sample No.	Temperature (^{o}C)	pH	EC (µs/cm)	TDS (ppm)
1	22	7.49	4450	2337
2	23	7.51	2510	1147
3	24.5	7.89	4640	2926
4	20.5	7.61	6940	5264
5	21.5	7.59	4280	3022
6	20	7.46	6151	4362
7	23	7.54	2680	1405
8	24	7.45	2838	1579
9	23	7.79	3972	2780
10	21	7.52	3060	1769
11	22	7.69	5125	3041
12	23	7.54	4977	2983
13	24	7.65	4261	1985
14	24	7.79	4320	2826
15	21	8.19	3102	2241
16	22	7.29	6820	3170
17	23.5	8.20	3959	2639
18	24	8.13	5850	3492
19	21	7.69	3856	2039
20	20	7.73	3050	2165
Mean ±sd	22.35 ±1.4	7.68 ±0.24	4342 ±1324	2659 ±981
Range	20-24.5	7.29-8.20	2510 -6940	1147 -5264
Libyan Standards	-	6.5- 8.5	-	500- 1000

Water Hardness
The analysis of groundwater samples show that the total hardness values of the samples ranging from 80-1045 ppm, Table (3). The values of total hardness in six water samples (30%) set within the allowable limit of the Libyan Standard Legislation for drinking water [14]. The explanation for this difference in total hardness values may the

prevailing type of salts in the soil, as well as may due to the concentration of industrial and household pollutants that pose to the soil and surface water [1, 18].

Table (3) Show that the values of calcium hardness of Shebna groundwater rang from 43.2-536 ppm, where that 16 samples of water samples (80%) have calcium hardness higher than permitted limit allowed by Libyan standard legislation for drinking water [14]. The values of hardness of magnesium for groundwater samples are shown in the table (3), these values range from 36.7-523 ppm. However, all the samples have high magnesium hardness, where the extent allowed by the Libyan Standard Legislation for drinking water is ranging from 30-150 ppm.

Chloride ion

The concentration of Chloride ion in Shebna groundwater samples ranged between 400- 2960 ppm (table (3). However, these values were all higher than the limit allowed by the Libyan Standard Legislation for drinking water, which states that the maximum concentration of chloride ion in the drinking water sets at 250 ppm [**14**]. It is not known that a high concentration of chlorides in the water has any trace toxic to humans or animals, but the presence of a high concentration of ions such as chlorides, calcium and magnesium leads to increased influence corrosive. Even more, The increase of chloride ion concentration more than 100 ppm impart a taste salty to water [**1**]. Chloride salts are widespread in nature in different forms include sodium, potassium and calcium salts. Chloride salts, can reach the groundwater by wastes resulting from agricultural, industrial and sewage [**12**].

Nitrate ion

The Libyan standard legislation for drinking water sets nitrate ion limits at 45 ppm [**14**]. The results in Table (3) show that the values of nitrate ion of the groundwater samples for Shebna region are located within the allowable limit, except for sample 11, where nitrate ion concentration arrive to 66.9 ppm. However, nitrate ion itself is harmless to human health, but it provides an idea about the possible presences of objectionable bacteria. Also high levels of nitrate ion can cause methemoglobinemia or "blue baby" disease [**19, 20**]. The microbiological analysis of smaple 11, table (5), indicates that sample 11 is free from organisms. Therefore, the high concentration of nitrates ion in sample 11 may due to the addition of nitrogen fertilizers in large quantities and it travels with irrigation water to groundwater [**21**].

Sulphate ion

Table (3) shows that the concentration of sulfate ion in water of Shebnas` wells are ranged between 78.5-342 ppm. This range indicates that the content of sulfates ion in all samples is less than the maximum limit allowed by the Libyan Standard Legislation for drinking water [**14**]. In fact, sulfate salts are present in most natural water. The most important sources of sulphate ion in water are the dissolving of some salts such as calcium sulfate, or mixing sulfur dioxide in the air with rain water or snow [**22**].

Sodium and Potassium Contents

The concentration of sodium ion in Shebna groundwater ranged from 95.1 -709 ppm, Table (4). The levels of sodium ion in all samples are higher than 20 ppm, which is the minimum permitted limit of sodium ions that allowed by the Libyan Standard Legislation for drinking water. However, there are 85% of the water samples have a concentration of sodium ion higher than 200 ppm, which is the maximum permitted limit of sodium ions allowed by the Libyan standard legislation for drinking water [**14**]. High concentrations of sodium ions in drinking water have not any trace toxic effects to humans or animals, but those who suffer from diseases, such as blood pressure; heart; kidney and liver cirrhosis, need a special source of water for drinking [**19**].

The concentration of potassium ion in Shebna groundwater samples ranged from 2.43-46.0 ppm. The limit required by the Libyan Standard Legislation for drinking water of potassium ions should be in the range of 10-40 ppm. One sample of Shebna region wells (sample 2) has a level of potassium ion less than 10 ppm, and only two samples of Shebna wells have a level of potassium ion higher than 40 ppm (sample 4 and sample 18), while the concentration of potassium ion in the other samples were all within the permitted range of Libyan Standard Legislation for drinking water [**14, 19**].

Table (3):Chemical parameters of groundwater of Shebna region

Sample no.	Total Alkalinity	Chloride	Total hardness	Ca-hardness	Mg-hardness	Sodium	Potassium	Nitrate	Sulphate
1	252	960	553	282	271	343	12.2	1.32	216
2	252	400	308	162	146	95.1	2.4	0.81	78.5
3	256	1440	685	362	323	437	18.7	1.37	178
4	280	2720	1045	522	523	709	43.0	0.42	342
5	320	1280	741	382	358	465	28.4	2.65	214
6	330	2960	80.1	43.2	36.9	698	13.0	0.42	313
7	176	560	372	193	179	181	3.24	1.22	81.9
8	268	600	404	214	190	216	3.24	1.48	89.7
9	356	1200	605	313	292	411	29.2	0.76	238
10	400	560	517	282	235	242	15.0	2.79	92.8
11	268	1120	869	452	417	455	24.2	66.9	214
12	248	1360	701	370	331	473	25.0	3.89	182
13	260	880	396	196	200	314	10.8	0.69	123
14	268	1360	629	342	287	361	18.3	1.14	197
15	292	960	637	352	285	141	13.3	1.07	215
16	284	1120	1041	536	505	455	15.8	3.21	265
17	208	880	909	460	449	384	26.1	3.05	213
18	267	1600	937	471	466	484	46.0	0.84	265
19	190	880	476	241	235	321	11.1	0.93	137
20	240	720	657	332	325	332	24.5	2.86	185
Mean ±sd	271 ±52.6	1178 ±55.3	628 ±252.7	325 ±127.7	303 ±125.6	376 ±160.1	19.2 ±11.89	1.62 ±1.07*	192.0 ±74.7
Range	176-400	400-2960	80.1-1045	43.2-522	36.9-523	95.1-709	2.4-46.0	0.42-3.89	78.5-342
Libyan Standards	-	200- 250	200- 500	75- 200	30-150	20-200	10- 40	≥45	200-400

All values in the table are the average of three readings, and in ppm unit. .
**The mean is the average of 19 reading without sample 11.*

Heavy metals Contents

In this work, the concentrations of some heavy metals, namely copper; zinc; chromium and iron in groundwater samples of Shebna region were determined, table (4). The concentrations of these metals in all samples were less than the maximum allowed limits set by the Libyan Standard Legislation for drinking water [**14**].

Table (4): The content of some heavy metals in Shebna groundwater

Sample no.	Cr	Zn	Fe	Cu
1	< 0.05	0.011	0.079	0.050
2	< 0.05	0.008	0.040	0.012
3	< 0.05	0.019	0.063	0.069
4	< 0.05	0.007	0.089	0.080
5	< 0.05	< 0.003	0.066	0.030
6	< 0.05	< 0.003	0.039	0.020
7	< 0.05	< 0.003	0.101	0.044
8	< 0.05	0.010	0.072	0.051
9	< 0.05	0.016	0.077	0.070
10	< 0.05	< 0.003	0.038	0.018
11	< 0.05	0.015	0.092	0.024
12	< 0.05	0.021	0.081	0.029
13	< 0.05	< 0.003	0.041	0.060
14	< 0.05	0.013	0.045	0.025
15	< 0.05	0.008	0.050	0.033
16	< 0.05	0.029	0.076	0.075
17	< 0.05	< 0.003	0.058	0.036
18	< 0.05	0.022	0.083	0.050
19	< 0.05	< 0.003	0.049	0.041
20	< 0.05	< 0.003	0.037	0.062
Mean ±sd	<0.05	0.011±0.008	0.064±0.021	0.044±0.020
Range	-	< 0.003- 0.029	0.037-0.101	0.012- 0.080
Libyan Standard	0.05	5- 15	0.1-0.3	0.01-1.0

**Each value in the table is the average of three reading, and in ppm unit.*
**The sensitivity of atomic absorption spectrophotometer are 0.05 and 0.003 ppm for Chromium and zinc elements respectively.*

Microbiological Analysis

The results of the microbiological analysis of water samples are present in the table (5).The **TC** for the samples range from 0 to > 300 CFU /1mL. However, the **MPN** method was used to detect the **TCF**, **FCF** and ***E.Coli*** bacteria in Shebna water samples. Table (5) shows that the values of **MPN** in 100 mL of water sample for the **TCF** range from 2 to <1100 and for the **FCF** range from 0 to 43. The ***E.Coli*** bacteria is detected in eight (40%) water samples. These results indicate that the groundwater samples of Shebna region exposed to contamination from human or animal faeces. This contamination may due to the shallow wells, with depths of 15- 30 m, which makes the groundwater vulnerable to mixing with sewage pollution. However, Shebna region is lacking the modern sanitation systems. In some cases, the nearness of the water well to the dump tank may lead to an increase in the possibility of leakage of sewage into wells [**23**].

The Libyan standard legislation for drinking water stressed the necessity of drinking water to be free from microorganisms. Comparing the results of the microbiological analysis of Shebna region with limits set by Libyan Standard Legislation indicates that the groundwater samples are unfit for drinking, washing and other purposes for human use [**14**].

Table (5): Microbiological analysis of Shebna groundwater

Sample no.	Total Account of (TC) (CFU/mL)	*Total Coliform* (T.C.F) MPN/100mL	*Faecal Coliform* (FCF) (MPN/100mL)	*Escherichia Coli*
1	300 <	83	9	+
2	280	43	7	+
3	0	9	0	NA
4	20	23	0	NA
5	320	1100	16	+
6	300	460	23	+
7	0	43	43	+
8	100	4	4	-
9	80	15	9	+
10	300	15	0	-
11	0	4	0	NA
12	0	2 >	Na	NA
13	10	4	0	NA
14	40	4	0	NA
15	10	2 >	NA	NA
16	150	2 >	NA	NA
17	60	2 >	NA	NA
18	90	83	15	+
19	300<	9	9	+
20	160	150	0	NA

**CFU/1mL: Colony Forming Unit per 1mL.; *MPN: Most Probable Number; *NA: Not Applicable*

CONCLUSION

In this study, 20 groundwater samples from Shebna region were analysed. The study relied on the appointment of a number of physical and chemical properties in addition to the microbiological analysis to detect the suitability of water samples for drinking and domestic. It was concluding that the most physical, chemical and microbiological values that determined for these samples were above the permitted limits set by Libyan standard legislation for drinking water. However, samples were unsuitable for drinking and other domestic uses.

The study recommended for the routine monitoring the groundwater quality and applying the treatment processes of the water before consumption. Also, the need to accelerate the establishment of sanitation system to save the groundwater supplies in the region.

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