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Preliminary Environmental Assessment of the Quality of Some Groundwater and Springs in Al-Jabel Al-Akhdar, Libya

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Abstract: The purpose of this study was to investigate the quality of the water in the Jabal Al-Akhdar region, northeastern Libya. Water samples were collected from 15 springs and 47 water wells during the summer and winter seasons of 2017. The aim of this study is to assess the quality index for drinking water (WQI) which provide great importance to human health. As well as for irrigation purposes (IWQI). SAR and %Na were calculated to classify both surface and groundwater sample for various purposes. The statistical analyses indicated that the TDS of surface and groundwater comes within the category of fresh water (TDS < 1000 mg/l) which it is appropriate for consumption and is monitored at all sits except at Massah and Appolo springs northwest of the study area. This might be related to the problem of solid and liquid waste accumulating on the surface without treatment. The results show that 93% and 85% of surface and groundwater samples are within the highest desirable category whereas the remainder samples for both fall within the moderate to maximum allowable range. It also found that SAR value comes within the category of low sodium hazard. Moreover, the USSL salinity diagram indicates that all of the water samples used in the study fall under (good to moderate) zone. Also, The results indicate that all of the surface water in the study could be commonly classified as type (Good/ Excellent) and (Doubtful/Excellent). In general, the constant monitoring of traditional water quality in the studied area is necessary which helps appropriate management and sustainable development in regards to natural resources.

Key words: Drinking water quality · Irrigation water quality · Hydro chemical analyses · The U.S. salinity · SAR · Groundwater · Springs water

INTRODUCTION

Libya is an arid region and one of the North African countries facing severe water scarcity due to rapid domestic development [1]. Groundwater and spring water are believed to serve as the principal water sourcesin Jabel Al-Akhder in northeast Libya, particularly within the study area [2, 3]. Agriculture is the major occupation of the people who live in the study region, and they rely greatly on groundwater and spring water for drinking, domestic use, livestock and agriculture [4]. Water ratings are used not only to determine whether it is fit for human consumption, but also to determine its ability to support agricultural, industrial, recreational, and commercial uses, and aquatic life. Regular monitoring of the quality of freshwater resources is necessary to ensure long-term sustainability [5] and the water quality index describes several water quality parameters relevant to specific beneficial uses. It is an indicator of the combined effects of [6]. However, the rapid increase in agricultural activity in the study area, along with environmental factors Such as runoff, sewage and other pollutants with water stress can deteriorate over time, affecting human health [7, 8].

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The information offered in this study on traditional water resources, such as groundwater and spring water, is sparse. Therefore, the existing water chemistry data for spring water (wells) and groundwater in this study are focused on presenting convincing evidence for the study area's drinking water quality and appropriateness for irrigation purposes. As a result, the current study seeks to assess the quality of surface water in the Al Jabal Al Akhdar region (Eastern Libya) by water quality index (WQI) for assessment of drinking water quality and water chemistry analysis for assessing suitability for irrigation (IWQI). Andgroundwater quality [9-15].

MATERIALS AND METHODS

Study Area: The study location is northeast of the Jabel Al-Akhder region bounded by latitudes 32°56"N to 32°34"N and 22°38"E to 21°50"E. It occupies an area of about 2,100 km^2 and has an average altitude varying at various levels from 100 to 400 m above sea level. The height of the study area varies from 0 to 876 m above mean sea level (Fig. 1). Al Jabal Al Akhdar region has a subtropical Mediterranean climate. The annual average rainfall is 400 mm, of which it falls in the fall and winter seasons [16]. There are no permanent bodies of water in the plains, except for Wadis and springs (Wadis) that flow only during the rainy season, and especially when springs are increasing. All spring discharges in the study area are average (40 L/S), recognizing that the quality of spring water is as important as its quantity. In addition, groundwater is the most important natural resource in Jabal Al Akhdar. Agriculture is the primary economic activity in this region. Therefore, many groundwater wells and springs in the study area were surveyed and evaluated for quality and suitability for drinking and irrigation, as described here in the study.

Collection of Water Samples: Water samples were taken from 47 wells (groundwater) and 15 fountains (springs) selected in the study area of Al Jabel Al-Akhder region both in the winter and summer of 2017-2018. Distilled water-washed polyethylene bottles (500 ml) were used for sampling, with three replicates set for each sampling. At the time of water sampling, each well was thoroughly rinsed two or three times, and spring water was sampled. These bottles were tightly capped and labeled for chemical and physical analysis.

Method of Analyses: The pH and electrical conductivity (EC) were measured immediately after sampling using a digital conductivity meter. Water samples collected in the field were obtained from the American Public Health Association [17]. Sodium (Na^+) and potassium (K^+) were measured by frame photometry. Total hardness (TH) as $CaCO_3$-, calcium (Ca^{2+}), carbonate (CO_3-), bicarbonate (HCO_3-), and chloride (Cl^-) were analyzed by volumetric methods. Sulfate (SO_4^{2-}) was estimated using a colorimetric method. Sodium adsorption rate (SAR) and % Na^+ are calculated to assess suitability of water quality for drinking and agriculture. It was calculated using the standard formula of [18-20]. Water quality was classified using the National Salinity Chart 1954. All water samples were collected from different locations in the study area, as indicated by the geographic coordinates of the sampling sites (Table 1).

Data Analysis: Correlations between measured water quality parameters are of great importance in many

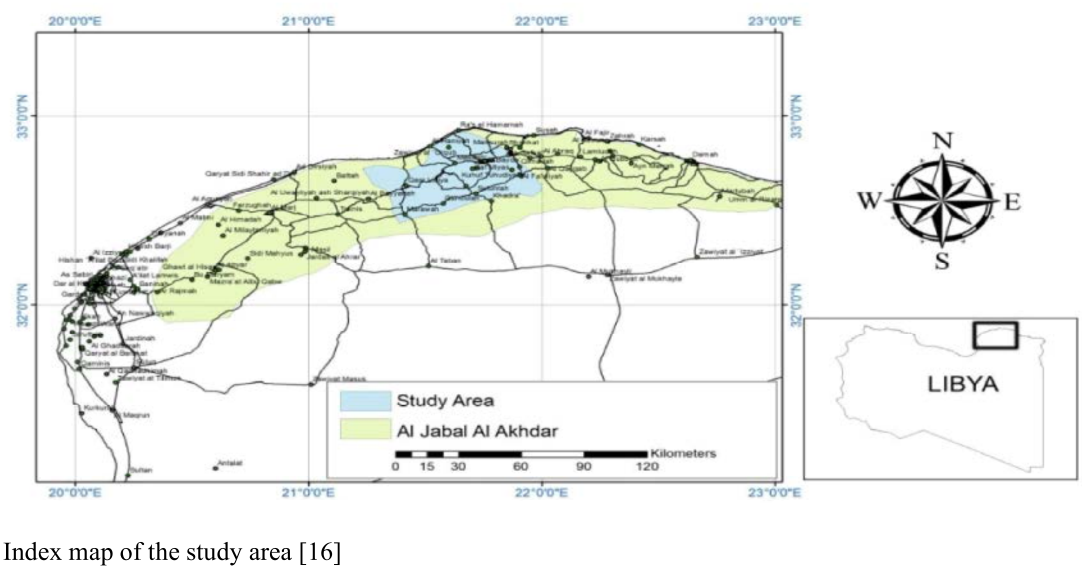


Fig. 1: Index map of the study area [16]

environmental data analysis tasks. These are especially important in model building such as regression analysis. A standard Pearson correlation matrix was performed on the relationships between the physicochemical parameters measured for various spring and well water samples. A statistically significant test of the Pearson correlation value by hypothetical t-test using p-values of 0.05 and 0.01 indicates whether what was observed in the sample is expected to be true in the experiment. It was created using Interactive Data Language Software (IDL), a programming language used for data analysis. It is popular in certain scientific fields such as astronomy, atmospheric physics, and medical imaging. (See the following websites, https://en.wikipedia.org/wiki/IDL).

Calculation of Water Quality Index (WQI): Originally, the Water Quality Index (WQI) was developed by Horton [21] in the United States by selecting the 10 most commonly used water quality variables such as dissolved oxygen (DO), pH, alkalinity and chlorides, etc. It has been widely applied and accepted in European, Asian and African countries [22, 23]. Furthermore, a new WQI similar to Horton's index has also been developed by the group of Brown *et al*. [24] and then by Cude [25] which was based on weights to individual parameter [22]. Recognized as a powerful tool to provide a comprehensive picture of surface and groundwater quality, the WQI is a ratio that reflects the integrated impact of various water quality variables [14, 15]. A WQI for drinking purposes was established using 19 values of physicochemical parameters for each sample in different seasons of winter 2017, summer 2017 and winter 2018. They were pH, TDS, TAK, TH, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, NH_4^{+}, Cl^{-}, PO_4^{3-}, NO_3^{-}, NO_2^{-}, SO_4^{2-}, HCO_3^{-} and DO.

The following steps were used in the calculation for WQI:

Firstly, weighted parameters was calculated by using the following equation

$$W_i = 1/(SI_i) \tag{1}$$

Secondly, proportionally constant was calculated by using the following equation:

$$k_c = 1/\sum_{i=0}^{n} W_i \tag{2}$$

Thirdly, the relative weight of each parameter was calculated using the following equation:

$$Rw_i = k_c \times W_i \tag{3}$$

The summation of parameters relative weight equal one.

Fourthly, a quality rating scale Qi for each parameter is computed by dividing its concentration in each water sample by its respective standard according to the Guideline of the Libyan National Center for standardization and meteorology and Ministry of Commerce [26] and the result is multiplied by 100 using the following equation:

$$Q_i = 100 \times \frac{C_i - C_o}{SI_i - C_o} \tag{4}$$

where Ci value of the water quality parameters obtained from the analysis, please note that the concentration of chemical parameters in meq/L. SIi value of the water quality parameter obtained from LNCS&MC.

Co is equal zero for all parameters expect for pH = 7.0 and DO = 14.6.

Finally, the parameter water quality index Sli was computed as follows:

$$SI_i = Rw_i \times Q_i \tag{5}$$

The water quality index was computed according to the following equation:

$$WQI = \sum_{i=0}^{n} SI_i \tag{6}$$

Water conditions are classified using water quality index (WQI) values calculated according to (Table 2), as shown in the study [27, 14, 28, 29]. Water status is calculated according to the corresponding water quality index values in Table (3) based on the calculated water quality index values [27, 14, 29].

Calculation of Sodium Percentage and Sodium Adsorption Ratio (SAR): Sodium adsorption rate (SAR) and sodium percentage (Na%) are used in Wilcox and Riverside charts to understand water quality for irrigation purposes. Na % is calculated in relation to the relative proportions of **cations** present in water using the following formula, with ion concentrations expressed in meq/l: using the following formula:

$$\%Na = \frac{Na^+}{Na^+ + K^+ + Mg^{2+} + Ca^{2+}} \times 100 \tag{7}$$

The SAR is calculated from the ratio of sodium to calcium and magnesium, using the following formula:

$$SAR = \frac{[Na^+]}{\sqrt{\frac{[Ca^{2+}] + [Mg^{2+}]}{2}}} \tag{8}$$

Table 1: Geographical coordinates of the sample points

Well No	Location	Coordinates Longitude	Latitude	Altitude (m)
1	Hakaash	21.334	32.481	120
2	Aleiata	21.334	32.5	129
3	Shkhnu	21.364	32.51	142
4	Bufuruh	21.371	32.445	504
5	Almushtal	21.375	32.451	514
6	Almustawsaf	21.375	32.45	517
7	Sayidi khalid	22.252	32.463	406
8	Sarusra	22.231	32.43	403
9	Almaleab	22.232	32.444	469
10	Dughush	22.225	32.452	462
11	Eulwat Alsharif	22.184	32.472	554
12	Alqiba	22.145	32.453	609
13	Aleamarat	22.14	32.46	579
14	Bawawazinih	22.142	32.453	607
15	Sixteen	22.022	32.47	676
16	Bualhimria	22.104	32.455	625
17	Alhasak	22.08	32.471	667
18	Al Qayqab	22.012	32.433	702
19	Almueadini	22.011	32.432	718
20	Altariulat	22.002	32.47	678
21	Wadi Aleaysh	21.52	32.481	627
22	Alwahda	21.52	32.484	626
23	Albaqara	21.504	32.483	628
24	Qernadah	21.544	32.432	675
25	Al Faidiyah	21.544	32.411	752
26	Marawah	21.241	32.293	483
27	Qandulah	21.343	32.32	625
28	Suluntah	21.423	32.345	750
29	Omar Almokhtar	21.411	32.38	746
30	Antar Sima	21.464	32.455	623
31	Bo Safah	21.452	32.451	624
32	Almulk	21.44	32.452	619
33	'Um Alsafasaf	21.441	32.465	595
34	Mebirah	21.395	32.523	213
35	Qasr Alshayabin	21.433	32.5	332
36	Darnah	22.374	32.453	69
37	Alkhadamat	22.374	32.453	67
38	Al Edrah	22.374	32.453	70
39	Alsharika	22.374	32.453	73
40	Al wadi 2	22.381	32.451	76
41	Al wadi 4	22.381	32.452	70
42	Amwaylah	22.39	32.453	10
43	Al Tawfiq	22.39	32.451	64
44	Bo Esmail	22.394	32.45	42
45	Al Afriqi	22.394	32.45	53
46	Al Fatayh	22.395	32.44	248
47	Al Hasadi	22.422	32.43	246

Spring No	Location	Coordinates Longitude	Latitude	Altitude (m)
1	Massah	21.619	32.756	472
2	Ayn Mara	22.38	32.75	430
3	Dapposia	22.281	32.833	283
4	Magga	22.268	32.716	517
5	El-Guppa	22.248	32.763	628
6	El-Agdir	22.021	32.726	714
7	El-Gaigab	22.022	32.726	722
8	Stouwa	22.11	32.856	306
9	El-Huffra	21.874	32.828	555
10	Appolo	21.852	32.823	567
11	El-Feltro	21.962	32.865	244
12	Karsaa	22.404	32.822	256
13	El-Belad	22.619	32.728	142
14	Bo-Mansour	22.61	32.702	160
15	El-Bieda	21.751	32.793	583

Table 2: Standard Values of water quality index (WQI)for drinking purposes

Parameters	Standard Values (SI_i)	Weight (Wi)	Relative Weight (Rw_i)
Temperature	30	0.033333	0.019818
EC	2300	0.000435	0.000258
pH	8	0.125	0.074317
TDS	1000	0.001	0.000595
TAK	200	0.005	0.002973
TH	500	0.002	0.001189
Ca	200	0.005	0.002973
Mg	50	0.02	0.011891
Na	200	0.005	0.002973
K	20	0.05	0.029727
NH_4	3	0.333333	0.198178
Cl	250	0.004	0.002378
PO_4	5	0.2	0.118907
NO_3	45	0.022222	0.013212
NO_2	3	0.333333	0.198178
SO_4	1	0.666667	0.396356
HCO_3	200	0.005	0.002973

$$k_c = 1/\sum_{i=1}^{17} W_i = 0.595 \qquad R_w = \sum_{i=1}^{17} k_c \times W_i = 1$$

There is a close relationship between the irrigation SAR and the extent to which Na+ is absorbed [30]. High concentrations of dissolved ions in water can adversely affect the physicochemical properties of plants and soils, leading to reduced productivity and destruction of soil structure [30, 31].

There is a close relationship between SAR value in irrigation and the extent to which Na^+ is absorbed [30]. In fact, high concentration of dissolved ions in water can affect plants, physicochemical properties of soils and can lead to lower productivity and destruction of soil structure [30, 31].

RESULTS AND DISCUSSION

Physicochemical Characteristics: In this section, the most important measured physicochemical parameters such as T, EC, TDS, and pH values are discussed for their significance in water classification. Statistics of physicochemical parameters of springs and groundwater in the study area (Tables 4 and 5) were measured in the following ranges during the rainy and dry seasons of 2017, (15.5-19.9°C) or (19.4-20.6°C) range during the rainy season in 2017. On the other hand, the groundwater temperature during the rainy season in 2017 is in the range of (12.8-22.9°C) and (19.9-22.1°C). There is no World Health Organization temperature index value, but colder water is better when it is warmer [32]. As shown in Fig. 2 (a&b), the EC values of spring water ranged from (503 to 1097 µS/cm) in winter 2017 and (500 to 1300 µS/cm) in summer 2017. On the other hand, the groundwater EC values ranged from (435 to 3285 µS/cm) in winter 2017

Table 3: Categorization of water status based on the values of water quality index [29]

WQI values	0 - 25	26 - 50	51 - 75	76 - 100	100 - 150	Above 150
Water Status	Excellent	Good	Poor	Very poor	Unsuitable	Unfit for all
Recommended Usages	Drinking, Irrigation and Industrial	Domestic, Irrigation and Industrial	Irrigation and Industrial	Irrigation	Restricted use for Irrigations	Proper treatment required before use

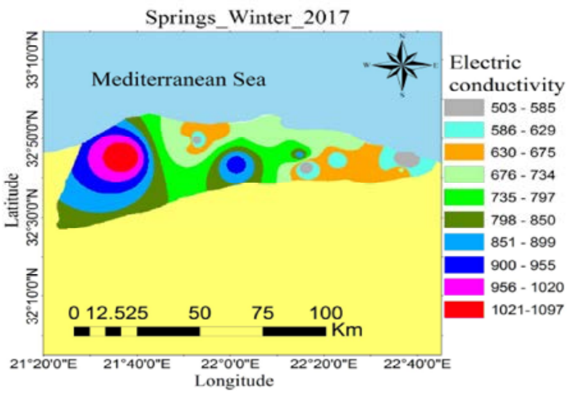
Table 4: Statistical summary of physicochemical parameters for the springs water

	Winter 2017 (Average)					Summer 2017 (Average)				
Parameters	Min	Max	Mean	Med	STD	Min	Max	Mean	Med	STD
Temp (°C)	15.50	19.90	18.06	18.30	1.23	19.40	20.60	20.12	20.30	0.38
pH	7.10	7.86	7.35	7.35	0.23	7.12	7.52	7.28	7.24	0.10
EC (µS/Cm)	503.00	1097.0	724.07	691.00	176.20	500.00	1300.00	773.00	740.00	207.10
TDS (mg/L)	312.00	768.00	450.79	433.00	122.10	300.00	780.00	469.90	444.00	129.10
TH (mg/L)	141.70	323.60	241.70	226.90	57.38	199.20	349.70	274.50	287.70	53.64
Ca^{2+} (mg/L)	37.00	96.00	71.14	73.00	19.10	60.00	112.00	84.71	79.00	19.41
Mg^{2+}(mg/L)	9.00	21.00	15.57	17.00	4.13	11.00	22.00	15.29	16.00	3.02
Na^{+} (mg/L)	10.00	34.00	15.79	14.00	6.64	15.00	40.00	26.29	28.00	8.42
K^{+} (mg/L)	2.60	3.50	3.01	3.10	0.30	1.62	11.35	4.85	4.86	2.53
NH_4^{+} (mg/L)	0.13	0.90	0.54	0.61	0.24	0.08	0.79	0.45	0.52	0.22
Cl^{-} (mg/L)	21.00	78.00	35.14	29.00	15.21	40.00	100.00	72.36	69.00	18.16
PO_4^{2-} (mg/L)	0.20	2.29	0.55	0.45	0.52	1.21	4.52	2.20	1.85	1.10
NO_3^{-} (mg/L)	12.00	42.00	23.79	23.00	7.51	12.00	44.00	23.07	25.00	8.64
NO_2^{-} (mg/L)	0.43	2.32	0.97	0.84	0.49	0.40	2.34	0.95	0.90	0.54
SO_4^{2-} (mg/L)	20.00	210.00	54.71	43.00	46.04	10.00	100.00	49.07	50.00	23.58
HCO_3^{-}(mg/L) L)	162.00	285.00	215.21	220.00	37.70	166.00	288.00	238.40	240.00	36.31

Table 5: Statistical summary of physicochemical parameters for the groundwater

	Winter 2017 (Average)					Summer 2017 (Average)				
Parameters	Min	Max	Mean	Med	STD	Min	Max	Mean	Med	STD
Temp (°C)	12.80	22.90	19.255	19.80	2.171	19.90	22.10	21.170	21.30	0.632
pH	7.10	7.88	7.324	7.30	0.158	6.90	8.10	7.265	7.21	0.228
EC (µS/cm)	435.00	3285.00	917.740	755.00	571.890	492.00	3411.00	1013.5.00	808.00	606.090
TDS (mg/L)	261.00	2300.00	597.270	455.00	422.490	295.00	2501.00	649.870	488.00	452.620
TH (mg/L)	106.20	624.70	273.950	237.90	105.120	145.80	696.40	312.490	280.40	105.900
Ca^{2+} (mg/L)	31.00	140.00	78.106	70.00	30.650	37.00	149.00	84.277	78.00	27.845
Mg^{2+}(mg/L)	7.00	67.00	19.191	17.00	9.570	11.00	79.00	24.830	23.00	12.112
Na^{+} (mg/L)	10.00	300.00	42.489	20.00	64.194	11.00	312.00	52.085	24.00	69.010
K^{+} (mg/L)	1.20	7.10	3.187	2.30	1.678	1.70	7.50	3.577	2.70	1.683
NH_4^{+} (mg/L)	0.25	1.30	0.581	0.55	0.211	0.39	1.30	0.693	0.70	0.179
Cl^{-} (mg/L)	22.00	900.00	96.468	38.00	170.750	29.00	981.00	126.040	58.00	190.880
PO_4^{2-} (mg/L)	0.12	2.67	1.080	0.90	0.611	0.58	3.89	2.090	2.10	0.887
NO_3^{-} (mg/L)	8.00	53.00	22.787	23.00	9.659	12.00	50.00	25.213	24.00	9.706
NO_2^{-} (mg/L)	0.20	1.10	0.501	0.49	0.180	0.33	1.10	0.599	0.61	0.160
SO_4^{2-} (mg/L)	18.00	320.00	67.255	50.00	59.326	10.00	370.00	91.830	53.00	77.541
HCO_3^{-}(mg/L) L)	101.00	348.00	195.760	176.00	69.393	116.00	362.00	209.530	191.00	68.925

and (492 to 3411 µS/cm) in summer 2017, as shown in Fig. 2(c&d). The pH values of the springs during the rainy season (winter) in 2017 varied between 7.1 and 7.86 in El-Belad and El-Gaigab respectively. In contrast, during the dry season (summer) of 2017, pH values varied within the range of 7.12 for Magga Springs to 7.52 for Massah Springs, as shown in Fig. 2(e&f). During the 2018 wet season (winter), the pH values of El Fetro springs ranged from 6.9 to 7.88 at Karsaa springs. During the 2017 winter season, groundwater pH levels varied slightly, ranging from 7.1 in Amwaylah well to 7.88 in Hakaash well, in the range of 0.78. It also varied in a range of 1.2, from 6.9 for Wadi Arish well to 8.1 for Al Afriqiwell, during the 2017 summer season, as shown in Fig. 2 (g&h). However, all pH values of water in the study area did not exceed the permissible limits for drinking water according to the WHO [32] standard specification of (6.5-8.5). The optimum pH is often in the range of 6.5-9.5 [33, 34]. Surface water total dissolved solids (TDS) varied over the 2017 winter season from 312 mg/L at Magga Spring to 768 mg/L at Massah Spring. It also ranged from 300 mg/L in the Magga spring of 2017 to 780 mg/L in the Massah spring. TDS also varied, ranging from 445 mg/L for AynMara Springs to 954 mg/L for Apollo Springs in 2018. Therefore,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Mediterranean Sea
Electric conductivity
503 - 585
586 - 629
630 - 675
676 - 734
735 - 797
798 - 850
851 - 899
900 - 955
956 - 1020
1021-1097
0 12.525 50 75 100
Km
Latitude
Longitude
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32°50'0"N
32°30'0"N
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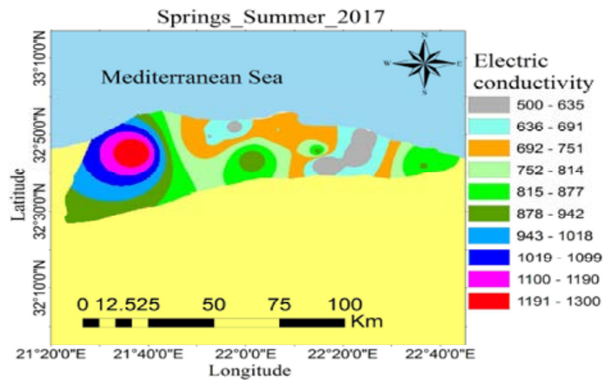
(a)


Springs_Summer_2017
Mediterranean Sea
Electric conductivity
500 - 635
636 - 691
692 - 751
752 - 814
815 - 877
878 - 942
943 - 1018
1019 - 1099
1100 - 1190
1191 - 1300
0 12.525 50 75 100
Km
Latitude
Longitude
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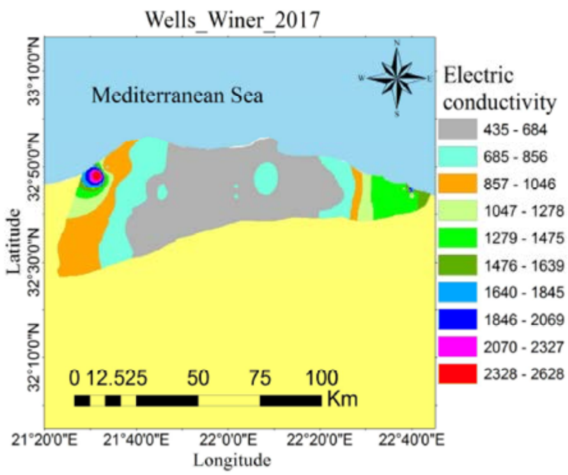
22°40'0"E

(b)


Wells_Winer_2017
Mediterranean Sea
Electric conductivity
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685 - 856
857 - 1046
1047 - 1278
1279 - 1475
1476 - 1639
1640 - 1845
1846 - 2069
2070 - 2327
2328 - 2628
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Km
Latitude
Longitude
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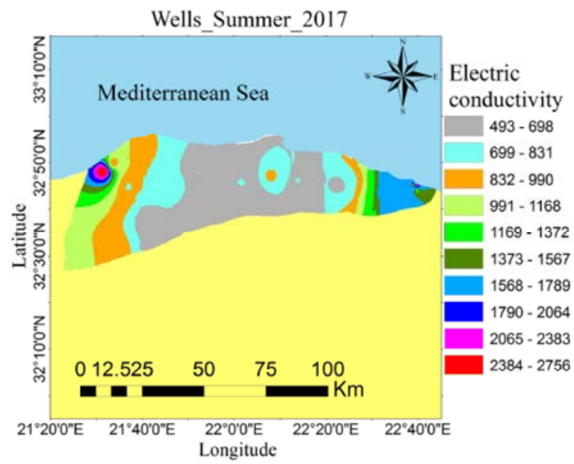
22°40'0"E

(c)


Wells_Summer_2017
Mediterranean Sea
Electric conductivity
493 - 698
699 - 831
832 - 990
991 - 1168
1169 - 1372
1373 - 1567
1568 - 1789
1790 - 2064
2065 - 2383
2384 - 2756
0 12.525 50 75 100
Km
Latitude
Longitude
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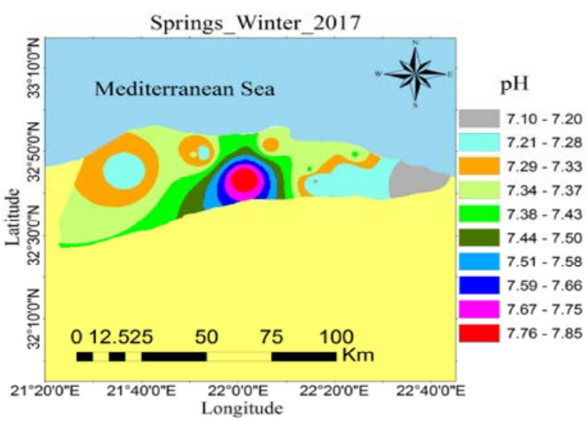
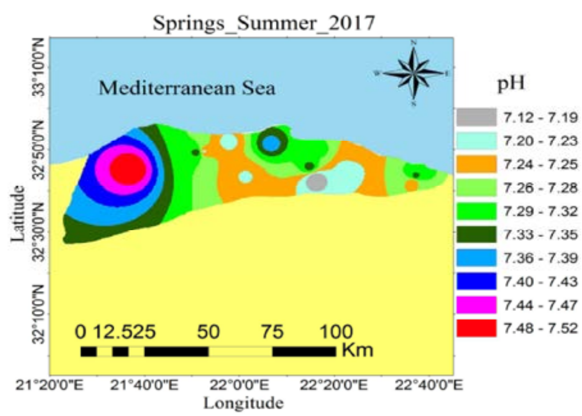
22°40'0"E

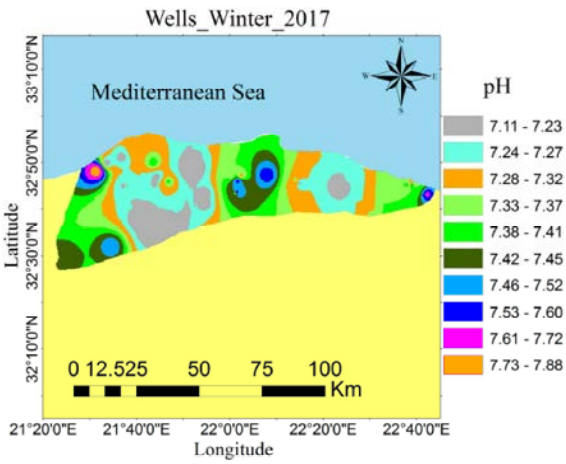
(d)


Springs_Winter_2017
Mediterranean Sea
pH
7.10 - 7.20
7.21 - 7.28
7.29 - 7.33
7.34 - 7.37
7.38 - 7.43
7.44 - 7.50
7.51 - 7.58
7.59 - 7.66
7.67 - 7.75
7.76 - 7.85
0 12.525 50 75 100
Km
Latitude
Longitude
33°10'0"N
32°50'0"N
32°30'0"N
32°10'0"N
21°20'0"E
21°40'0"E
22°0'0"E
22°20'0"E
22°40'0"E

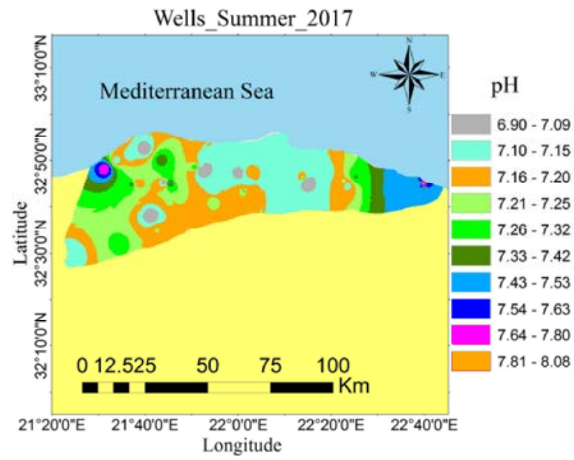
(e)


Springs_Summer_2017
Mediterranean Sea
pH
7.12 - 7.19
7.20 - 7.23
7.24 - 7.25
7.26 - 7.28
7.29 - 7.32
7.33 - 7.35
7.36 - 7.39
7.40 - 7.43
7.44 - 7.47
7.48 - 7.52
0 12.525 50 75 100
Km
Latitude
Longitude
33°10'0"N
32°50'0"N
32°30'0"N
32°10'0"N
21°20'0"E
21°40'0"E
22°0'0"E
22°20'0"E
22°40'0"E

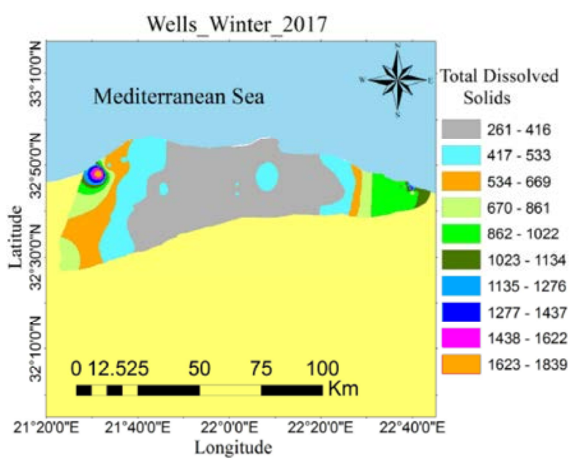
(f)



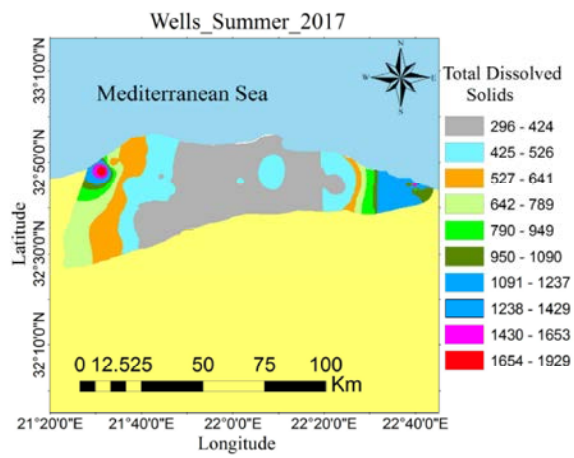
(g)



(h)



(i)



(j)

Fig. 2: Trend of seasonal variation of some water quality parameters in Al Jabal Al Akhder region in East Libya during winter, summer of 2017

all spring water analyses in the study area are classified as freshwater species (according to TDS < 1000 mg/L). In accordance with World Health Organization [32] and TDS classification criteria [35].

Groundwater TDS concentrations varied from 261 mg/L in the Omar Almokhtar well to 2300 mg/L in the Al Edrah well during the winter of 2017. TDS also varied during the 2017 summer season, ranging from 295 mg/L for the Al Qayqab well to 2501 mg/L for the Al Edrah well, as shown in Fig. 2(i&j).

Major Ions: Overall, the statistical analysis showed the strength of the relationship between the physicochemical parameters measured for various sources as shown in Tables (6 & 7), and groundwater samples as shown in Tables (8 & 9). Was performed to measure the spring water results showed that EC, TDS, and TH were highly positively correlated with NO_3, NO_2, SO_4, and NH_4. Groundwater results showed that EC, TDS, and TH were strongly and highly significantly correlated with all parameters except DO. On the other hand, pH values showed moderate and strong positive correlations with all parameters except PO_4, DO, NH_4 and NO_2.

In general, the magnitude of cation depletion was the same for surface waters in all seasons, in the order $Ca^{2+} > Na^{+} > Mg^{2+} > K^{+} > NH_4^{+}$. Calcium with sodium was the predominant cation at concentrations up to 93.35 and 72.25 mg/L. Concentrations of magnesium and potassium, on the other hand, were measured up to 21.75 mg/L and

Table 6: Pearson Correlation Matrix for the relationship between the physiochemical parameters of the surface water in winter of 2017, the symbol ● refers to the correlated parameters are statistically significant at the 0.05 and 0.01 levels, while □ refer to the correlated parameters are only statistically significant at the 0.05 level. The cells without such samples refer to the correlated parameters are not statistically significant at both 0.05 and 0.01 levels

	Temp	pH	EC	TDS	TH	Ca	Mg	TAK	Cl	PO_4	NO_3	Na	K	HCO_3	DO	SO_4	NH_4	NO_2
Temp	1.00																	
pH	0.22	1.00																
EC	0.15	0.59□	1.00															
TDS	0.14	0.40	0.96●	1.00														
TH	0.35	0.52	0.87●	0.85●	1.00													
Ca	0.39	0.48	0.84●	0.82●	0.96●	1.00												
Mg	0.11	0.42	0.59□	0.58□	0.67●	0.45	1.00											
TAK	-0.48	-0.31	0.13	0.29	0.08	-0.03	0.37	1.00										
Cl	0.11	0.26	0.84●	0.92●	0.70●	0.67●	0.50	0.24	1.00									
PO_4	0.45	-0.11	-0.15	-0.18	-0.01	0.03	-0.13	-0.43	-0.13	1.00								
NO_3	0.15	0.22	0.56□	0.62□	0.74●	0.68●	0.60□	0.31	0.47	-0.25	1.00							
Na	0.27	0.27	0.82●	0.90●	0.73●	0.68●	0.57□	0.16	0.97●	-0.07	0.47	1.00						
K	-0.26	-0.34	0.19	0.27	0.09	0.15	-0.13	0.33	0.35	0.23	-0.23	0.29	1.00					
HCO_3	0.04	0.82●	0.58□	0.43	0.60□	0.61□	0.31	-0.18	0.21	-0.31	0.49	0.19	-0.29	1.00				
DO	0.32	0.00	-0.14	-0.20	-0.22	-0.22	-0.15	-0.53	-0.10	0.33	-0.35	-0.07	-0.38	-0.35	1.00			
SO_4	0.01	-0.06	0.71●	0.83●	0.50	0.47	0.36	0.46	0.85●	-0.07	0.32	0.81●	0.53	-0.11	-0.05	1.00		
NH_4	0.03	0.50	0.42	0.39	0.39	0.38	0.28	0.00	0.28	-0.43	0.58□	0.28	-0.28	0.71●	-0.44	0.03	1.00	
NO_2	0.13	0.00	0.72●	0.87●	0.75●	0.71●	0.52	0.46	0.86●	-0.18	0.72●	0.83●	0.30	0.11	-0.20	0.84●	0.24	1.00

Table 7: As in Table (6) but for the surface in the summer of 2017

	Temp	pH	EC	TDS	TH	Ca	Mg	TAK	Cl	PO_4	NO_3	Na	K	HCO_3	DO	SO_4	NH_4	NO_2
Temp	1.00																	
pH	-0.23	1.00																
EC	0.00	0.71●	1.00															
TDS	-0.01	0.71●	0.98●	1.00														
TH	-0.27	0.66●	0.81●	0.79●	1.00													
Ca	-0.27	0.63□	0.75●	0.71●	0.98●	1.00												
Mg	-0.10	0.38	0.57□	0.66●	0.51	0.31	1.00											
TAK	-0.04	0.39	0.40	0.37	0.13	0.08	0.25	1.00										
Cl	0.07	0.51	0.83●	0.84●	0.71●	0.64□	0.60□	0.04	1.00									
PO_4	0.15	0.18	0.04	0.003	-0.10	-0.10	-0.04	0.40	-0.20	1.00								
NO_3	-0.05	0.37	0.70●	0.68●	0.55□	0.51	0.37	0.46	0.53	-0.23	1.00							
Na	0.06	0.46	0.86●	0.85●	0.69●	0.62□	0.56□	0.15	0.97●	-0.23	0.60□	1.00						
K	-0.23	0.23	0.48	0.42	0.62□	0.64□	0.17	0.01	0.48	0.13	0.26	0.49	1.00					
HCO_3	-0.61□	0.19	0.11	0.11	0.12	0.05	0.31	0.62□	-0.12	0.26	0.29	-0.04	-0.06	1.00				
DO	-0.28	0.01	0.13	0.11	0.13	0.13	0.02	0.08	0.17	0.44	-0.17	0.18	0.17	0.37	1.00			
SO_4	0.20	0.15	0.48	0.55□	0.17	0.06	0.50	0.33	0.51	-0.35	0.76●	0.56	-0.02	0.08	-0.26	1.00		
NH_4	-0.06	0.26	0.31	0.34	0.66●	0.64□	0.35	-0.01	0.33	-0.21	0.51	0.28□	0.29	0.07	-0.15	0.27	1.00	
NO_2	0.01	0.66●	0.93●	0.92●	0.62□	0.56□	0.50	0.56□	0.66●	0.08	0.77●	0.72●	0.27	0.24	0.07	0.58●	0.16	1.00

6.45 mg/L, respectively. Furthermore, the depletion of groundwater cations was the same in the following order: Na^+> Ca^{2+}> Mg^{2+}>K^+> NH_4^+. As expected, sodium and calcium were the predominant cations at concentrations up to 161.5 and 93 mg/L, respectively, and magnesium was measured at potassium concentrations up to 45 and 4.6 mg/L, respectively.

In contrast, the magnitude of surface water anion decline in winter 2017 was HCO_3^- > SO_4^{2-}> Cl^-> NO_3^-> PO_4^{3-}> NO_2^-. Bicarbonate and sulfate were the major anions with high concentrations up to 233 and 146.5 mg/L, respectively. On the other hand, the chloride concentration was 128 mg/L. In addition, the decrease of anions in surface water in the summer of 2017 was HCO_3^-> Cl^-> SO_4^{2-}> NO_3^->PO_4^{3-}>NO_2^-. Bicarbonate and chloride were the major anions with high concentrations up to 233 and 76 mg/L, respectively. The sulfate concentration was 55 mg/L. In addition, the decrease of groundwater anions in winter and summer in 2017 was the same in the order of Cl^-> HCO_3^-> SO_4^{2-}> NO_3^-> PO_4^{3-}> NO_2^-. As expected, chloride with bicarbonate was the predominant anion with concentrations up to 506.5 and 289 mg/L, respectively. The sulfate concentration was 190 mg/L.

Three major water types are monitored in the study area using Trilinear piper diagrams [36], as shown

Table 8: As in Table (6) but for the surface water in winter of 2018

	Temp	pH	EC	TDS	TH	Ca	Mg	TAK	Cl	PO_4	NO_3	Na	F	K	HCO_3	DO	SO_4	NH_4	NO_2
Temp	1.00																		
pH	-0.16	1.00																	
EC	-0.05	-0.34□	1.00																
TDS	-0.05	-0.34□	0.99 ●	1.00															
TH	0.03	-0.40□	0.70●	0.70●	1.00														
Ca	-0.17	-0.41□	0.53●	0.53●	0.74●	1.00													
Mg	0.25	-0.05	0.34□	0.33□	0.50●	-0.22	1.00												
TAK	0.14	-0.57●	0.46●	0.46●	0.53●	0.30	0.38□	1.00											
Cl	0.03	-0.12	0.26	0.26	0.53●	0.57●	0.04	-0.04	1.00										
PO_4	0.56●	-0.35□	0.04	0.04	0.02	-0.09	0.14	0.16	0.01	1.00									
NO_3	0.14	-0.13	0.43●	0.43●	0.36□	0.49●	-0.10	0.09	0.37□	0.21	1.00								
Na	0.00	-0.08	0.58●	0.58●	0.47●	0.47●	0.08	0.04	0.50●	0.06	0.38	1.00							
F	0.48●	-0.05	0.02	0.02	0.04	-0.27	0.41□	-0.03	-0.14	0.30	0.15□	0.10	1.00						
K	0.12	-0.17	0.53●	0.53●	0.57●	0.49●	0.19	0.10	0.52●	0.13	0.18	0.51●	0.07	1.00					
HCO_3	-0.27	-0.09	0.53●	0.53●	0.62●	0.47●	0.29	0.47●	0.14	-0.32	0.16	0.06	-0.17	0.22	1.00				
DO	-0.33□	-0.01	0.06	0.06	0.03	0.11	-0.10	-0.06	-0.004	0.01	0.02	0.10	-0.002	0.06	-0.02	1.00			
SO_4	0.09	-0.01	0.35□	0.34□	0.37□	0.35□	0.09	0.09	0.56●	0.10	0.66●	0.52●	0.21	0.16	0.13●	0.09	1.00		
NH_4	-0.12	-0.02	0.46●	0.46●	0.27	0.16	0.18	0.19	0.20	0.03	0.14	0.33□	-0.11	0.57●	0.08	0.09	0.17	1.00	
NO_2	0.16	-0.06	0.36□	0.36□	0.41□	0.39□	0.10	0.15	0.63●	0.03	0.56●	0.61●	0.14	0.32	0.10	-0.02	0.86●	0.23	1.00

Table 9: As in Table (6) but for the groundwater in winter of 2017

	Temp	pH	EC	TDS	TH	Ca	Mg	Cl	PO_4	NO_3	Na	K	HCO_3	DO	SO_4	NH_4	NO_2
Temp	1.00																
pH	0.06	1.00															
EC	0.14	0.56●	1.00														
TDS	0.13	0.54●	0.99●	1.00													
TH	-0.01	0.50●	0.88●	0.89●	1.00												
Ca	0.01	0.49●	0.79●	0.81●	0.95●	1.00											
Mg	-0.05	0.38●	0.82●	0.82●	0.81●	0.61●	1.00										
Cl	0.15	0.47●	0.96●	0.95●	0.77●	0.64●	0.81●	1.00									
PO_4	-0.08	0.22	0.65●	0.66●	0.70●	0.67●	0.56●	0.57●	1.00								
NO_3	0.06	0.46●	0.83●	0.83●	0.80●	0.74●	0.70●	0.78●	0.61●	1.00							
Na	0.16	0.49●	0.96●	0.96●	0.76●	0.66●	0.76●	0.99●	0.58●	0.79●	1.00						
K	0.07	0.35□	0.47●	0.49●	0.57●	0.65●	0.26	0.37□	0.47●	0.38●	0.39●	1.00					
HCO_3	-0.04	0.52●	0.79●	0.79●	0.77●	0.72●	0.64●	0.69●	0.57●	0.77●	0.71●	0.45●	1.00				
DO	-0.31□	0.14	0.20	0.20	0.32□	0.35□	0.18	0.14	-0.06	0.35□	0.16	0.27	0.19	1.00			
SO_4	0.18	0.62●	0.93●	0.92●	0.77●	0.68●	0.74●	0.93●	0.48●	0.74●	0.92●	0.50●	0.67●	0.22	1.00		
NH_4	-0.07	0.27	0.57●	0.56●	0.46●	0.30□	0.64●	0.63●	0.34□	0.76●	0.61●	0.00	0.48●	0.35□	0.48●	1.00	
NO_2	-0.05	0.12	0.40●	0.39●	0.31□	0.23	0.39●	0.43●	0.30□	0.66●	0.46●	0.03	0.43●	0.41●	0.30□	0.88●	1.00

in Fig. (3, 4 & 5). The results showed that the surface water type in 2017 was calcium sulfate only in the town of Massah, east of the study area. On the other hand, the water quality in the wet and dry seasons in 2017 is calcium bicarbonate (shallow fresh groundwater) at all sites.

On the other hand, winter 2017 groundwater species are classified as calcium bicarbonate due to seawater intrusion, but only as calcium sulfate in the city of Derna, east of the study area, and as sodium chloride in Hakaash, far east of the study area will be, in addition, the water species in the groundwater in the summer of 2017 in the study area are classified as calcium bicarbonate, but in the east and west of the study area, it is classified only as calcium sulfate and sodium chloride. This is due to the intrusion of seawater, which has characteristics specific to its terrain. The classification of each water sample was projected onto a map using GIS software, as shown in Fig. 5.

Water Quality Index (WQI): To examine the quality of surface water in the Al-Gabal Al-Akhder area pH, TDS, TAK, TH, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, NH_4^{+}, Cl^{-}, PO_4^{3-}, NO_3^{-}, NO_2^{-}, SO_4^{2-}, HCO_3^{-}, were considered in the calculation of the water quality index (WQI) (Table 2). We also used the World Health Organization [32] limits as a reference. The calculated WQI for the 14 water samples corresponds to the water quality index calculated for potable zoning. WQI values for surface water in winter and summer in

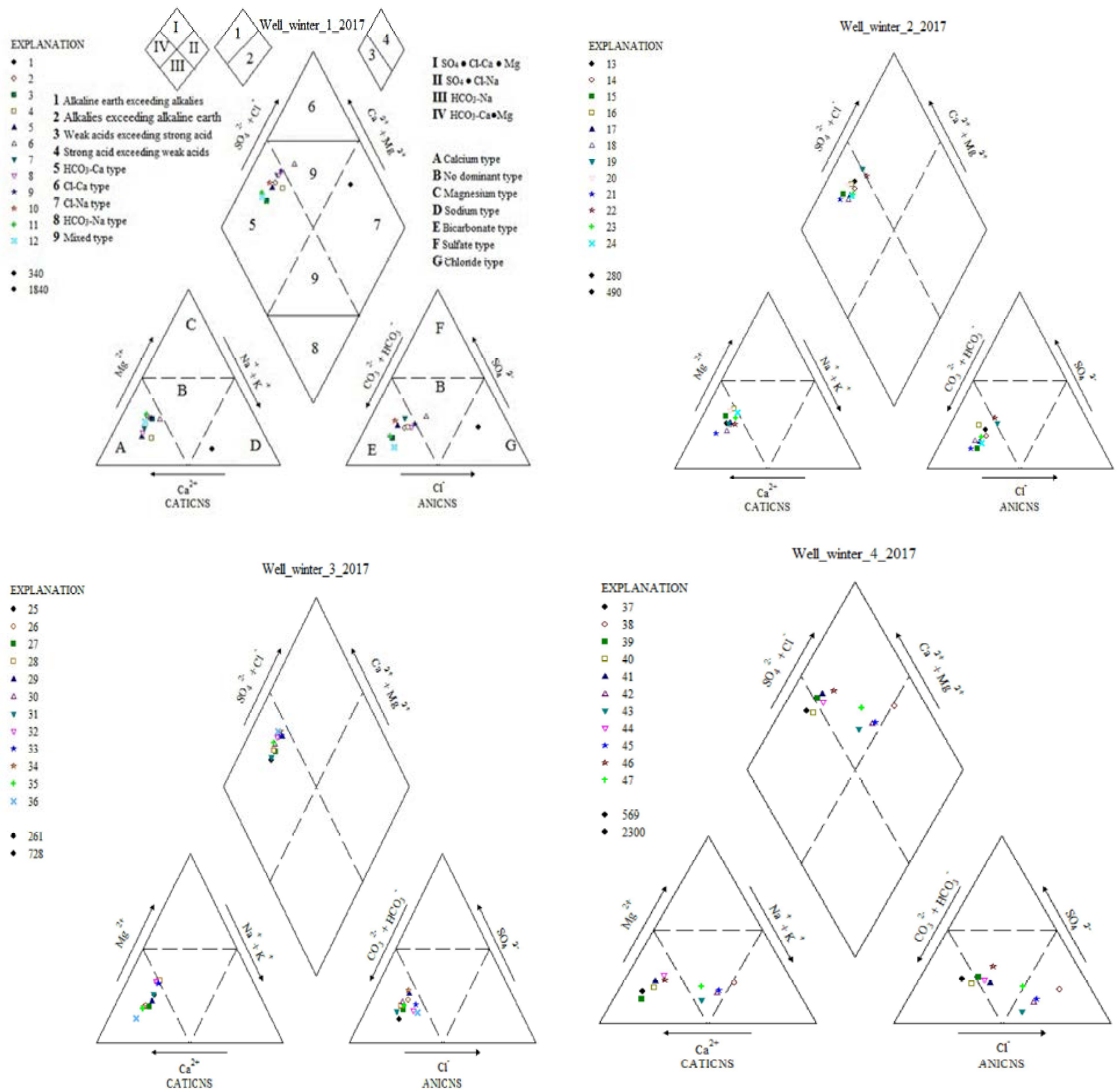


Fig. 3: Piper diagram for the groundwater in winter of 2017 for irrigation purpose. The water samples were divided into four groups; each group contains only 12 samples to clarifying the plot for further interpretations. The left diagram in the above panel contains a different legend clarification for the first 12 samples.

2017 were found to be in the range of (17.41-46.58) and (23.10-47.51), respectively. On the other hand, surface water conditions in 2017 (winter and summer) were rated as excellent (14.28% and 7.14%) and good (75.72% and 92.86%), respectively. WQI values for groundwater in winter and summer in 2017 ranged from (23.13-62.97) and (26.58-68.86), respectively. On the other hand, groundwater conditions in winter 2017 were very good, with 85.31% good and 6.38% bad, accounting for 8.31% of the total sample. Furthermore, groundwater conditions in summer 2017 were classified as good for 91.5% of all samples and bad for 8.5%.

Water Quality for Irrigation Purposes: All samples are appropriate for rinsing according to the sodium content and electrical conductivity in Fig. 7. The SAR data plotted in Fig. 8 of the U.S. Salinity Chart show that winter and summer surface water IWQI values for 2017 are in the

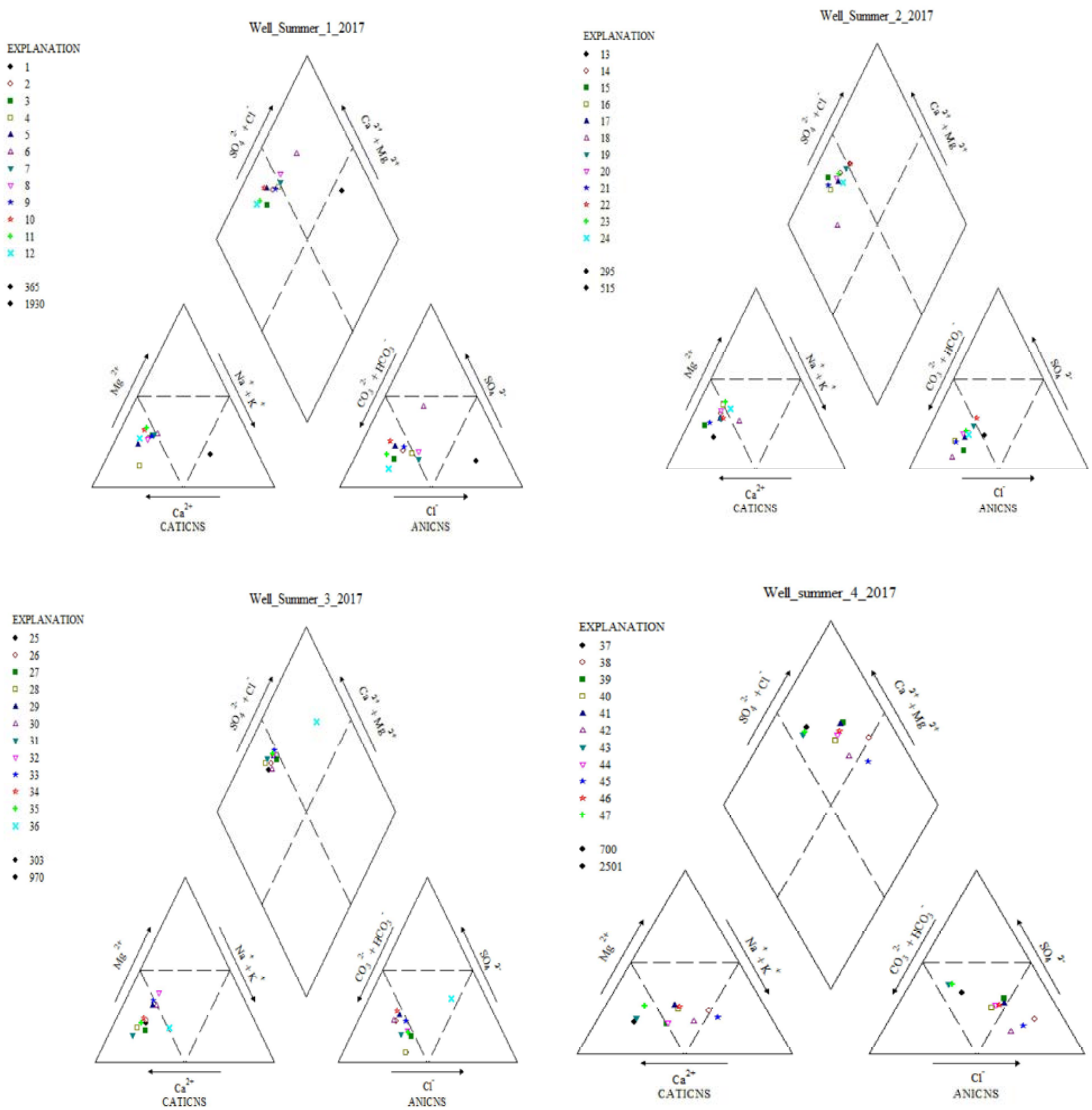


Fig. 4: As in Figure 3 but for summer 2017.

range of (13.95-48.51) and (14.32-49, 95) lei. I was. On the other hand, surface water conditions in 2017 (winter and summer) were rated good (50% and 21.43%) and good (50% and 78.57%) across the sample. In addition, groundwater IWQI values ranged from (16.92-139.04) in winter 2017 to (15.69-148.53) in summer 2017. Respondents in 2017 were rated very bad (21.28%, 6.38% respectively), good (61.7%, 70.21%), bad (8.51%, 12.26%) and very bad. (4.26%, 4.26%)and non-compliant in (4.25%, 6.38%) of the total samples, Analytical data plotted on the U.S. salinity chart conclude that all surface and groundwater samples are within the zone (good to moderate) (Fig. 7). Surface water samples falling within the C2-S1 and C3-S1 groups are therefore suitable for irrigation. Additionally, some of the studied area's water samples should not be utilized in soils with limited drainage. Generally, continuous water quality monitoring is necessary for farmers and irrigation authorities to formulate water policies.

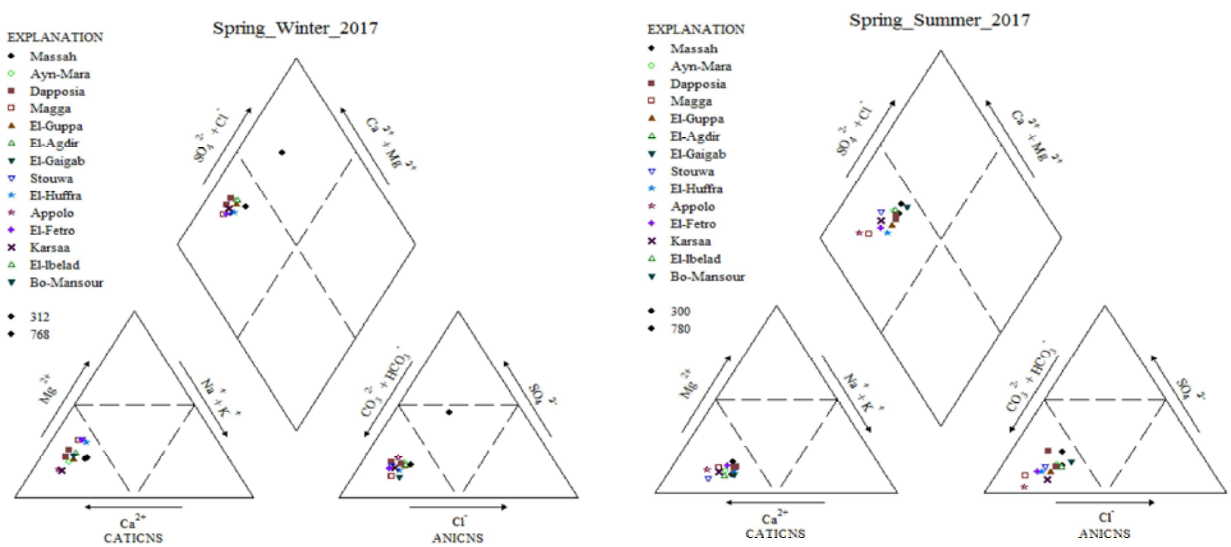


Fig. 5: Piper diagram showing the chemical composition of surface water samples for this study in winter and summer of 2017

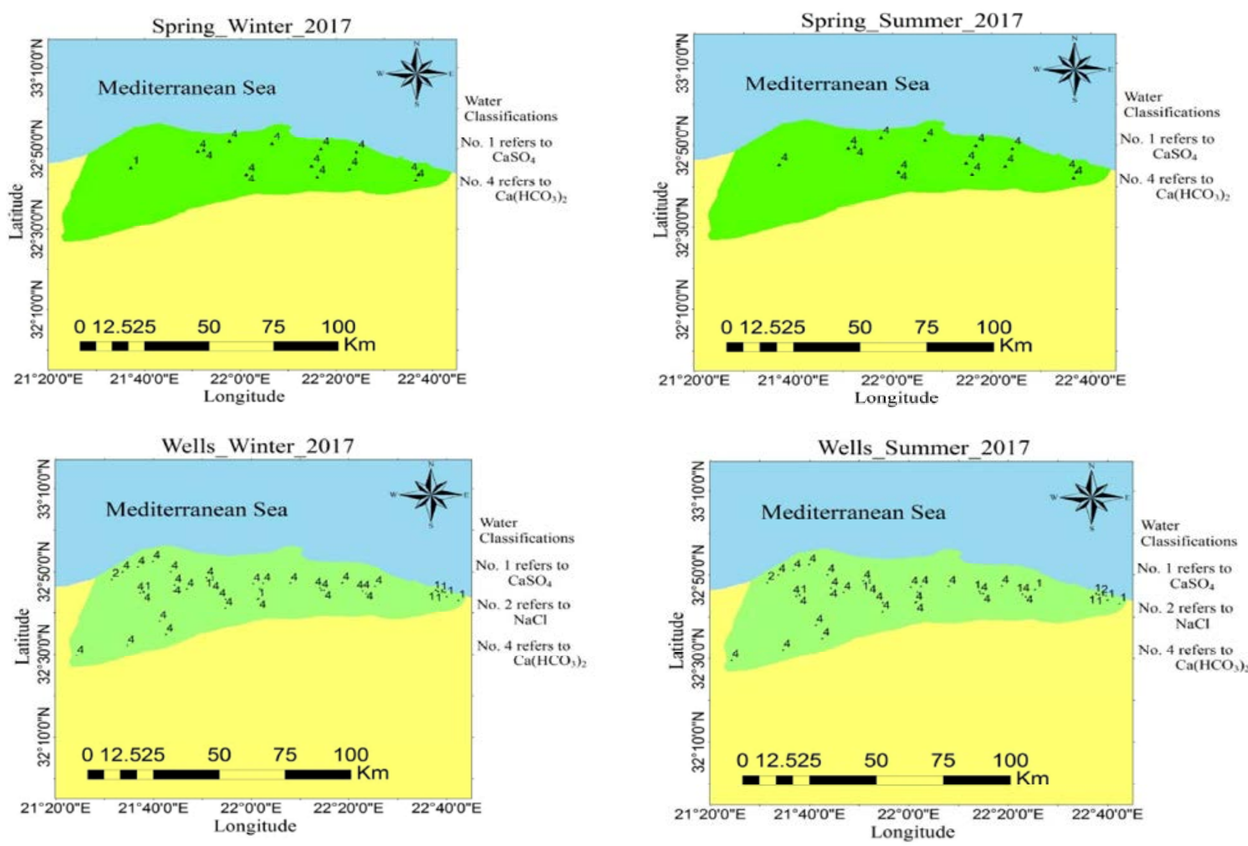


Fig. 6: Water Classifications for the study area by projection the results form a piper diagram in a map using GIS software.

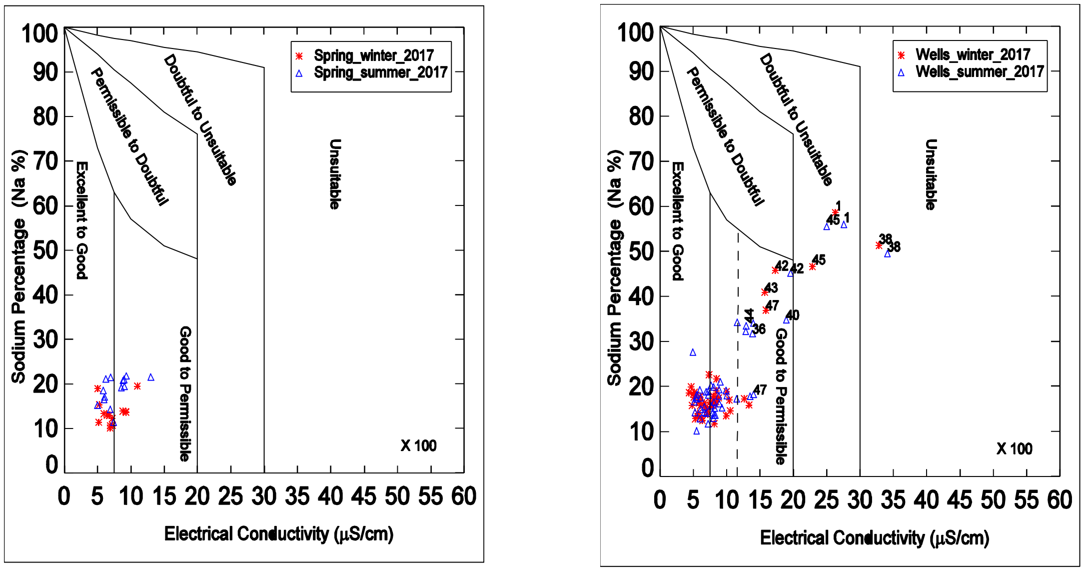
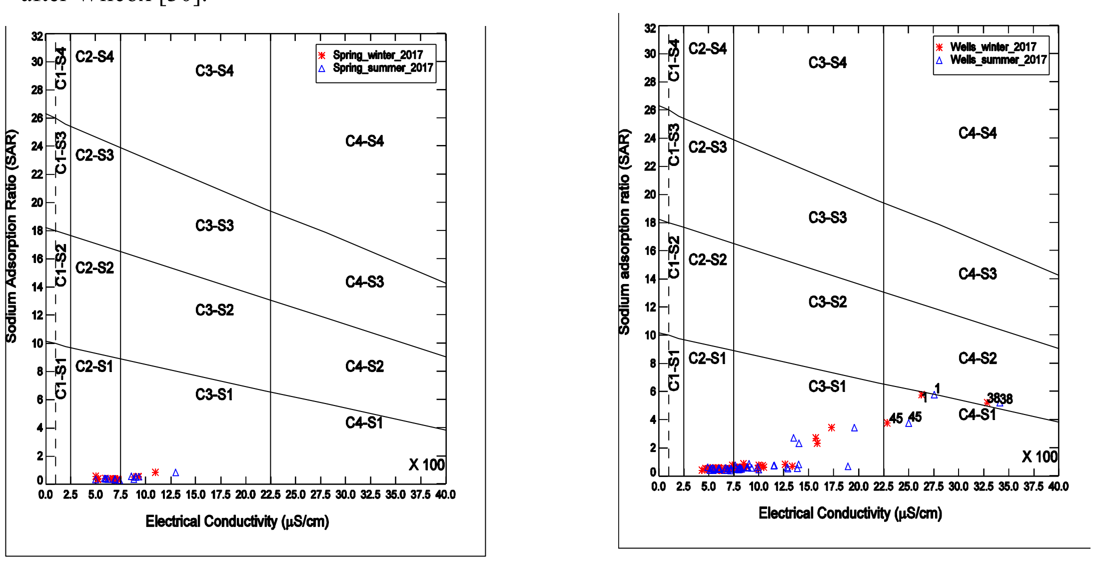


Fig. 7: Rating for the surface & the groundwater's in relation to sodium percentage (Na %) and the electrical conductivity after Wilcox [30].



(a) Surface water.

(b) Groundwater.

Fig. 8: Rating of springs& groundwater samples in relation to Salinity Hazard & Alkali Hazard
(a) Surface water. (b) Groundwater.

CONCLUSION

This study assesses surface and groundwater quality in the Al Jabal Al Akhder region in northeastern Libya. Due to its physicochemical properties, water is neutral to basic (6.9 < pH < 8.1). Depending on the water quality, the calculated WQI values are between 17.41 and 68.86, ranging from excellent to good drinking water quality. Depending on the water quality, the calculated IWQI values ranged from 15.69 to 148.53, ranging from water quality suitable for irrigation to water quality unsuitable for irrigation. According to SAR values and %Na values, all sample locations are suitable for irrigation purposes. The Massah City study region is not suited for irrigation purposes. However, it should be noted that small amounts of metallic elements are present in springs and groundwater in the Al Jabal Al Akhder area. These results provide a baseline reference for future surveillance in the Al Jabal Al Akhder region.

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