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RESEARCH PAPER

Assessment of Ground water Quality for Drinking purpose in the Shaqlawa Area, Erbil-KRI

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A B S T R A C T:

Physical, chemical and biological properties of some artesian wells in Shaqlawa area were done, through collecting water samples for 12 artesian wells seasonally (Spring, summer, autumn and winter) during 2016, which distributed in Shaqlawa, Harir and Permam area.

In ground water samples of study areas, electric conductivity was range between 252-2300 µS/cm, with mean values for all 12 wells were range between 474.8-1575.5 and overall mean was 689.3.The pH of study samples is neutral or around neutrality and ranged between 7.0 and 8.4 With mean values ranged between 7.2-8.2 and the overall mean 7.6 and standard deviation of 0.4 and agreed with WHO guidelines for drinking water purpose. Sodium and potassium levels were ranged from 1 to 310 and 0.1 to 8.18 mg/L. Turbidity is one of the parameters for the acceptability of drinking water quality. WHO, guidelines for turbidity is < 5 NTU.

The overall mean value of total alkalinity in studied water samples was 278.5 mg $CaCO_3$/L.

The levels of sulfate in groundwater samples of the study area ranged between 11.8 to 314 mg/L. The overall mean and STDEV is 72.7 and 71.6 respectively. . Concentration of total hardness in the studied area were ranged between 160 and 560 mg $CaCO_3$/L. Furthermore, calcium dominated magnesium in studied well water.

Nitrate levels in groundwater samples were low. Microbiological analysis of studied water samples was zero, except in two samples. Water quality index or studied parameters in groundwater samples were excellent.

KEY WORDS: Drinking water; Water Quality; Shaqlawa; Kurdistan Region, Iraq
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1. INTRODUCTION :

Groundwater (GW) is important source of drinking water and its quality relies upon many factors including the composition of interaction of

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Assessment of physical and chemical characteristics groundwater is important to estimate its uses. The interaction of mineral in soil and ground water processes will affect the water quality, The chemical composition of water is based primarily on the minerals which have dissolved in it. In addition, the chemical composition of water is modified by ion-exchange equilibrium. There are some environmental conditions affecting on the water chemistry such as type of rock, climate, relief, vegetation and time (Rajmohan 2004).

Physical and concoction prepare influencing ground water (Fittes 2002). General physical, chemical and biological parameters are temperature, pH, alkalinity, hardness, solids, turbidity (Zuane, 2010).

In this work an endeavor has been made to evaluate the physical and chemical parameters of ground water like pH, electrical conductivity, hardness, total dissolved solids, alkalinity, phosphate, sulfate, nitrate, chloride and so on., the gathered information were contrasted and standard qualities suggested by WHO (Rao 2013).

Hydrochemical evaluation of groundwater systems is usually based on the availability of a large amount of information concerning groundwater chemistry (Hossien 2004). Quality of groundwater is equally important to its quantity owing to the suitability of water for various purposes (Subramani et.al., 2005). Groundwater chemistry, in turn, depends on a number of factors, such as general geology, degree of chemical weathering of the various rock types, quality of recharge water and inputs from sources other than water rock interaction. Such factors and their interactions result in a complex groundwater quality (Guler and Thyne 2004).

Groundwater is an important water resource for drinking, agriculture and industrial uses in study area. The present study was conducted to investigate certain physical, chemical and biological characteristics of artesian wells in Shaqlawa city, Harir and Permam area to determine its suitability for drinking purpose.

2. MATERIALS AND METHODS

Physical, chemical and biological properties of 4 Artesian wells situated in each of Shaqlawa city, Harir and Permam sub-districts were focused on through water sampling for a year seasonally (Spring, Summer, Autumn and Winter) particularly for ground water that used for drinking during 2016.

Water samples were gathered in polyethylene container and taking after standard methods portrayed by (APHA, 1998 and Parsons, *et al*., 1984) for water examination, all water samples were tested within first 4-6 hour. Alkalinity, chloride, magnesium and calcium were measured by titration technique, while total hardness measured by formulation. pH, EC and TDS were measured utilizing (pH-EC-TDS meter, HI 9812, Hanna instrument).

Sulfate was controlled by turbidimetric technique as indicated by (APHA, 1998). Sodium and potassium cations measured utilizing flame Photometer instrument. Turbidity was measured utilizing Turbidimeter (HF logical, inc. show BRF-15 CE). Most Probable number (MPN) was conducted according to (APHA, 1998).

WQI (Water quality index) for drinking water was used to evaluate groundwater samples according to WHO, (2004) for its suitability for drinking purpose through using the following formula:

$$WQI= \Sigma WIQI/\Sigma WI$$

All analyzed parameters of studied water groundwater samples were considered for WQI calculation except the bacteriological parameter.

2.1 Description of study area

a- Kurdistan covers about 65,000 km² in Iraq at 36.4103° N, 44.3872° E, The Region is geographically diverse, from hot and dry plains to cooler mountainous areas with natural springs and snowfall in the winter.

b- Erbil is a capital of Kurdistan of Iraq. Erbil covers about 18170 square kilometers. It is bounded to the north-west by Greater Zab River and to the south-east by Lesser Zab River. Located at 36.5571° N, 44.3851° E. The climate of the area is characterized by a wide diurnal and annual range of temperature (Figure 1 A).

c- Shaqlawa lies 51 km to the northeast of Erbil, at the bottom of Safeen mountain. Shaqlawa is situated between Safeen mountain and Sork mountain, and sits 1066 m above sea level. The city is known for its waterfalls, trees, and greenery.

In this review, 12 wells were secured through gathering information and data about water quality evaluation in the zone under review. All wells were dispersed in the area. Four wells situated in each of Shaqlawa districts located in Erbil Province, Harir and Permam sub-districts located in Erbil-Kurdistan Region of Iraq (Figure 1 A).

Erbil Province is the capital of Iraq Kurdistan district of and arranged in the north east of Iraq. Erbil region is the capital of Iraqi Kurdistan with around one million population and arranged in the upper east of Iraq. Its limits reached out from longitude 43° 15` E to 45° 14` E and from scope 35° 27` N to 37° 24` N (Goran, 2006, Shareef and Muhamad, 2012).

Study area is a memorable city and a Hill station in the Erbil Governorate in the Kurdistan area of Iraq (Toma, 2010)

Shaqlawa is sitting 56 km to north-east of Erbil city and situated in versant of Safeen mountain. Permam and Harir located 27 and 47km respectively and the atmosphere in the area has a place with the semi-parched Mediterranean type. It is described by cool, blustery winters from one viewpoint and long, hot, dry summers. Study areas describe by a prolific soil and presence of many water asset like snow and precipitation wellsprings of winter precipitation. The principle hydrogeological attributes are looked like by yearly precipitation run between 800-1000 mm/year, many springs are streaming in contemplated territory, these springs are spill out of Aqra-Bekhme and Pila Spi Formations. The primary hotspot for these springs are identified with aquifers fissured, fissured (Seeyan and Mirkel, 2014).

Kurdistan area of Iraq is a rocky land finds, where, Syria, Turkey and Iran meet. It has chains of high mountains, for example, Toros and Zagros mountains, which frames a couple of incredible curves of around 3000-4000 meters height. The topography of Kurdistan region extended from longitudinal of 43°15` E to 45° 14` E and from latitudinal of 37°27` N to 36° 34` N and spreads a territory of roughly 165 000 square kilometers (Maulood and Hinton, 1978).

Contemplate territory is situated at the High Folded Zone (support by figure of High folded zone in Erbil). The topographic zone reflected the geological structures straightforwardly which affected by nature of these developments, and difference in the imperviousness to degree for disintegration. In study zone see high and ridged area which is spoken to by most established development is Qamchuqa Formation furthermore to Bekhme and Pila Spi Formations, however in low help regions speaks to by clastic formations which is Kolosh, Gercus, Lower Fars and Upper Fars Formations. Khurmala arrangement was happened as a tongue in Kolosh Formation, and Avanah Formation happened in Gercus Formation. Limit of Pila Spi Formation was unconformable over Gercus Formation stores, limit of Pila Spi Formation was unconformable with Lower Fars Formation and limit of Upper Fars Formation was comparable with Lower Fars Formation. The primary hydrogeological attributes are looked like by yearly precipitation run between 800-1000 mm/year, many springs are streaming in contemplated zone, these springs are spill out of Aqra-Bekhme and Pila Spi Formations. The principle hotspot for these springs are identified with aquifers fissured, fissured (Sissakian and Youkhanna, 1978).

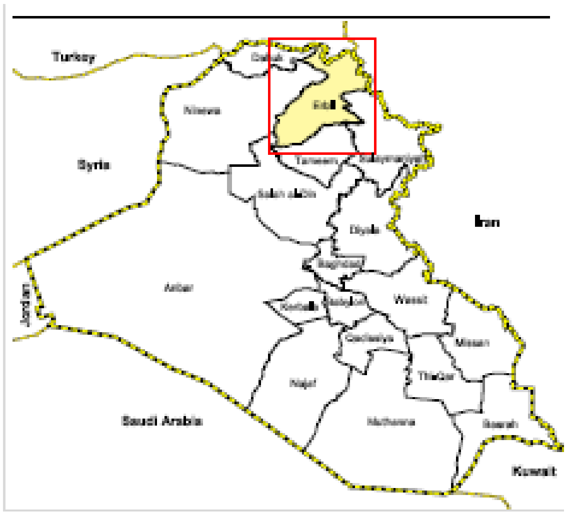

Figure 1: A - Map of Iraq.

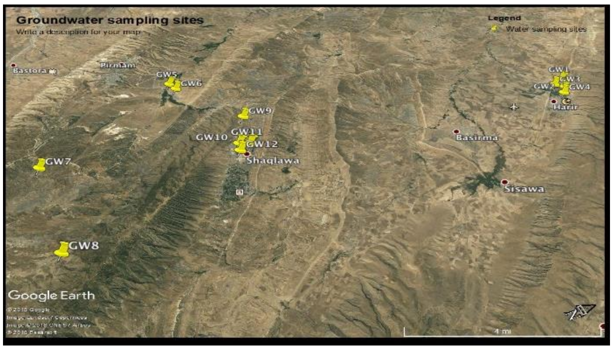

Figure 1: B - Study area

3. RESULTS AND DISCUSSION

According to WHO standards (2011) and IQS, Iraqi Standard (2009) EC value should not exceeded 1500 µS/cm^{-1}. In study areas, EC value was ranged between 252-2300 µS/cm^{-1}, with mean values for all 12 (Wells or GW) were range between 474.8-1575.5 and overall mean was 689.3. (as shown in table 1) and came in agreement with work done by (Toma 2010) on Shaqlawa water wells. Water with high mineral content tends to have higher conductivity, which is a general indication of high dissolved solid concentration of the water. Therefore, conductivity measurements can be used as a quick way to locate potential water quality problems (Mohsin *et al*., 2013)

The pH of water is referring to the measure of hydrogen ions concentration in water. It ranges from 0 to 14. In general, water with a pH of 7 is considered neutral while lower of it referred acidic and a pH greater than 7 known as basic. According to WHO standards pH of water should be 6.5 to 8.5 (Table 1). It is noticed that water with low pH is tend to be toxic and with high degree of pH it is turned into bitter taste. The pH is neutral or close to it as they all range from 7 to 8.4 with mean 7.6 and standard deviation of 0.4 and agreed with (WHO, 2006) standards for drinking water. Correlation coefficients were found between pH, EC, TDS, Alkalinity and SO_4.

Turbidity is one of the parameters for the acceptability of drinking water quality. WHO, guidelines for turbidity is < 5 NTU. All natural waters are turbid but generally surface more than ground water (APHA, 1998). The observed values in studied samples for turbidity were varied from 0.1 to 7.6 NTU, with mean values for all 12 Wells were range between 0.23-3.13 and overall mean was 1.0 (As shown in table 1), the high turbidity in drinking-water may be due to the presence of inorganic particulate matter and rainfall season, this came in agreement with (Toma, 2010) who worked on drinking water of Shaqlawa.

The term total dissolved solids refer mainly to the inorganic substances that are dissolved in water. The effects of TDS on drinking water quality depend on the levels of its individual components; excessive hardness, taste, mineral depositions and corrosion are common properties of highly mineralized water (Shivaprasad *et al.*, 2014) The overall mean of TDS was ranged from 308.6 to 1024.1 (As shown in table 1), according to the WHO standards (1000 mg/L) it is a natural range and its mean and standard deviations is 448 and 230.2 respectively. Alkalinity is the chemical measurement of a water's ability to neutralize acids, is the ability to resist changes in pH with respect to the addition of acid in water provides an idea of natural salts present in water upon the addition of acids or bases. Alkalinity of natural waters is due primarily to the presence of weak acid salts although strong bases may also contribute in extreme environments. Bicarbonates represent the major form of alkalinity in natural waters. Its standard level is 300 mg $CaCO_3$/L, the minimum limit of alkalinity in potable water is 200 mg/L. The maximum level is 755 mg/L which it is a high level. The mean value of alkalinity in the ground water of the study area was 278.5 mg/L with standard deviation of 117.4. This fluctuation in alkalinity level is normal for Kurdistan groundwater systems, this agreed with (Goran 2006) on the natural spring and surface water of Kasnazan and Dilope spring.

Hardness of water is caused by the presence of multivalent metallic cations and is largely due to calcium, Ca^{++}, and magnesium, Mg^{++} ions. Hardness is reported in terms of $CaCO_3$ (WHO, 2004). The maximum acceptable level of total hardness in drinking water according to WHO guideline is 500 mg $CaCO_3$/L (Toma, 2010). Concentration of total hardness in the studied area ranged between 160-560 mg $CaCO_3$/L with a mean and standard deviation is 311.5 and 91.7 respectively.

Calcium and magnesium are the two most common minerals that can cause alkalinity in water and the degree may increase as calcium and magnesium ion increases. This causes water to be hard and leads to aesthetic problems and bitter taste (Napacho *et al*., 2010). Its standard range is 200 mg $CaCO_3$/L. The maximum acceptable limit of calcium for domestic use is 75ppm and minimum range is 30 (Table 1), most hard-water ions originate from calcium carbonate, levels of water hardness are often referred to in terms of hardness as $CaCO_3$. The content of magnesium in the groundwater was significantly different and it ranged from 11 to 86 and its mean is 41.2 and its STDEV is 17.8, its affect the total hardness. Correlation coefficient were found between hardness, Ca, Mg, SO_4, NO_3

Sodium and potassium are chemicals commonly found in soils and rocks. Sodium is more mobile in soil than potassium and so it is used often as an indicator of human impacts to shallow ground water. Sodium is also a common chemical in minerals. Like potassium, sodium is gradually released from rocks. They belong to a group of chemicals called the "alkali earth metals, they readily dissolve in water. Mean concentrations of sodium and potassium from the Ground Water wells were 22.8 and 1 mg/L (Table 1) respectively, moreover, sodium and potassium were ranged from 1 to 310 and 0.1 to 8.18 mg. l^{-1} with STDEV of 57 and 1.3 respectively (APHA 1998). Sodium correlated significantly ($P<0.05$) with pH, EC, TDS, SO_4, Cl^{-1} and alkalinity.

Sulfate (SO_4) occurs naturally in groundwater. At high levels, sulfate can give water a bitter or astringent taste and can have laxative effects. As a precaution, water with a sulfate level exceeding 400 mg/L should not be used in the preparation of infant formula. The level of sulfate in groundwater in study area is low, between 11.8 milligrams per liter (mg/L) to 314 mg/L, its mean and STDEV are 72.7 and 71.6 respectively (APHA 1998).

Sodium and chloride are substances naturally exist in groundwater at low levels. They are commonly known as salt, or 'table salt. Sodium and chloride are substances that occur naturally in groundwater. They are also substances used by the human body to help it work well. But, certain human activities, such as salting roads, can increase levels in well water so that water taste or quality are impacted. Water containing 350 mg/L of chloride may have a detectable salty taste if the chloride came from sodium chloride (Maiti 2004). The recommended maximum level of chloride in study ground water is 494 and the minimum level is 2.31 mg/L, with a mean of 42.1 and the mean concentrations of sodium from the Ground Water wells is 22.8 mg/L (Table 1).

Natural nitrate levels in groundwater are generally very low (typically less than 10 mg/L NO_3), but nitrate concentrations grow due to human activities, such as agriculture, industry, domestic effluents and emissions from combustion engines. Its standard level is 50 mg/L, in the study area NO_3 levels ranged between 2 to 38, and its mean is 11.9 with STDEV of 9.9. The nitrate concentration in ground water under aerobic condition is 10 mg/L and depends strongly on soil type and the geological conditions (Gray, 1994).

Fecal coliform bacteria originate from intestinal tracts of animal and human indicate the possible presence of pathogenic organisms. In the present study, the recorded value for coliform bacteria (fecal coliform bacteria) values were ranged from 0 to 16 MPN/100ml, the indicated values 16 MPN/ 100ml mean that water is considered unsatisfied for drinking at GW1 during winter 2016 according to WHO guidelines (WHO, 2011). While in other sites have 2.2 MPN.100 mL or less (zero) and in the safe side for drinking purposes due to the chlorination effects (WHO, 2004). (Fripp *et al*., 2015 and Edberg *et al*., 2000).

It was observed that WQI values were ranged from 16.36 at GW3 during Spring season to 47.52 at GW11 during Spring season and ground water samples can be categorized into excellent water quality (Table 1 and Table 3), The mean value of WQI is 21.27 and considered safe for drinking purpose according to WHO, 2004 and Garcia-Avila *et al*., 2018. The "good" quality of studied water samples of Harir and Shaqlawa can be related to the measured parameters that was below maximum standards for drinking water purpose. Same results were obtained by Garcia-Avila *et al*., 2018 in Ecuador water systems.

Table 1: Physical and chemical properties of survived groundwater in Shaqlawa district-Erbil

Location	*Well No.*	*Season*	*Turbidity*	*pH*	*EC*	*TDS*	*T. Alkalinity*	*T. Hardness*	*Ca*	*Mg*	*Na*	*K*	*Cl*	*NO_3*	*SO_4*	*MPN*	*Mean*	*WQI*
Standard			5NTU	6.5-8	400 µµS.cm	1000 mg. l-1	300mg $CaCO_3$/L	500 mg $CaCO_3$/L	100mg $CaCO_3$/L	100mg. l-1	200mg. l-1	20mg. l-1	250mg. l-1	50 mg. l-1	250mg. l-1	0/100ml		
Harir 2	GW1	Spring	4.7	7.1	616	400.4	230	250	45	33.5	4	0.6	20	24	64	0	130.7	35.13
		Summer	0.6	8.1	462	300.3	180	175	48	13.5	2.6	0.6	15	7.5	61	0	98.1	19.59
		Autumn	0.2	7.9	581	377.65	220	300	80	24.5	5	0.7	25	26	59	0	131.3	19.00
		Winter	5.6	7.8	473	307.45	262	276	84	16.2	4.4	0.7	15	14	55	16	117.0	39.83
	Mean		2.78	7.7	533.0	346.5	223.0	250.3	64.3	21.9	4.0	0.7	18.8	17.9	59.8	4.0	119.3	
Harir 9	GW2	Spring	0.1	7.4	452	293.8	208	270	63	27.5	1.7	0.2	11	5.6	51	0	106.9	16.41
		Summer	3.3	7.8	475	308.75	260	245	75	14.2	2	0.4	10	6	49	0	112.0	30.09
		Autumn	0.4	7.3	500	325	210	220	40	29.3	2	0.3	15	5	56	0	108.5	17.24
		Winter	0.5	7.4	538	349.7	236	237	43	31.6	2.2	0.4	19	6	54	0	117.3	18.02
Mean			1.08	7.5	491.3	319.3	228.5	243.0	55.3	25.7	2.0	0.3	13.8	5.7	52.5	0.0	111.2	
Harir 16	GW3	Spring	0.2	7.3	516	335.4	240	210	52	19.6	1.8	0.2	13	2	58	0	111.8	16.36
		Summer	0.4	7.1	564	366.6	200	210	45	23.8	2	0.1	15	3	53	0	114.6	16.75
		Autumn	0.5	7.1	580	377	175	250	32	41.4	3	0.4	20	3	50	0	118.4	17.28
		Winter	2.3	7.1	692	449.8	250	320	32	58.4	4	0.4	20	12	49	0	145.9	25.20
Mean			0.85	7.2	588.0	382.2	216.3	247.5	40.3	35.8	2.7	0.3	17.0	5.0	52.5	0.0	122.7	
Harir 19	GW4	Spring	0.1	7.2	515	334.75	220	160	64	11	2.7	0.5	14	20	54	0	106.9	16.55
		Summer	0.3	7.0	592	384.8	220	245	52	28.1	3	1.3	20	28	59	0	126.2	17.65
		Autumn	0.5	7.3	604	392.6	231	267	61	28.0	4	1.2	23	32	68	0	132.3	19.29
		Winter	1.5	7.4	646	419.9	290	340	30	64.5	2	0.3	18	6.3	61	0	145.1	22.39
Mean			0.60	7.2	589.3	383.0	240.3	253.0	51.8	32.9	2.9	0.8	18.8	21.6	60.5	0.0	127.6	
Kore 6	GW5	Spring	0.1	7.9	923	599.95	275	425	94	46.4	18.5	1.4	41	27	108	0	196.0	19.66
		Summer	0.2	7.5	803	521.95	315	350	82	35.4	41	0.9	20	5	53	0	171.9	17.93
		Autumn	0.5	7.4	1003	651.95	350	560	160	39.3	24	1.8	55	38	65	0	227.4	21.60
		Winter	0.1	7.9	926	601.9	280	500	96	63.4	20.4	1.5	45	30	113	0	204.9	20.05
Mean			0.23	7.7	913.8	593.9	305.0	458.8	108.0	46.1	26.0	1.4	40.3	25.0	84.8	0.0	200.1	
Kore 3	GW6	Spring	0.1	7.2	252	163.8	220	400	96	39.1	11.8	1.8	45	5	141	0	105.3	17.00
		Summer	0.3	7.3	600	390	265	280	49	38.4	40	0.8	15	5	54	0	134.2	17.39
		Autumn	0.2	7.8	830	539.5	280	520	128	48.9	17	1.4	40	4	91	0	192.9	19.26
		Winter	1.47	7.9	757	492.05	260	450	112	41.6	15.6	1.7	40	4	104	2.2	174.6	24.29
Mean			0.52	7.6	609.8	396.3	256.3	412.5	96.3	42.0	21.1	1.4	35.0	4.5	97.5	0.6	151.8	
Qirzha	GW7	Spring	1.4	8.2	2100	1365	755	184	17.8	34.0	310	8.18	494	17.8	123.5	0	416.8	28.60
		Summer	0.4	8.2	985	640.25	351	456	40	86.6	77	2.5	36	26	288	0	230.5	22.09
		Autumn	0.52	8.1	917	596.05	378	426	36	81.8	72	2.3	34	33	295	0	221.5	22.49
		Winter	1.01	8.4	2300	1495	674	408	45.7	71.5	244	4.78	494	12.8	314	0	467.2	27.30
Mean			0.83	8.2	1575.5	1024.1	539.5	368.5	34.9	68.5	175.8	4.4	264.5	22.4	255.1	0.0	334.0	
Khoran	GW8	Spring	0.5	7.9	421	273.65	503	256	62.2	24.6	41.85	0.73	2.31	2.29	51.2	0	126.7	19.31
		Summer	0.2	8.2	516	335.4	256	312	40	51.6	4	0.6	16	6	195	0	133.9	18.82
		Autumn	0.3	7.9	532	345.8	238	319	36.5	55.5	55.3	0.52	21.4	11	185		139.1	18.95
		winter	0.6	8.1	430	279.5	529	269	65.8	25.6	1.87	0.682	2.31	2	11.8	0	125.1	19.99
Mean			0.40	8.0	474.8	308.6	381.5	289.0	51.1	39.3	25.8	0.6	10.5	5.3	110.8	0.0	131.2	
Shaqlawa kawaniyan	GW9	Spring	0.9	7.7	626	406.9	321	378	46	64.0	2.3	0.4	21	11	23	0	146.8	20.91
		Summer	0.5	7.9	685	445.25	275	267	42	39.5	3.4	0.5	21	2	14	0	138.7	19.00
		Autumn	0.2	7.5	593	385.45	220	238	45	30.6	4	0.4	25	12	31	0	122.5	17.25
		Winter	0.6	7.6	659	428.35	330	390	48	65.8	2	0.2	15	4	15	0	151.2	19.24
Mean			0.55	7.7	640.8	416.5	286.5	318.3	45.3	50.0	2.9	0.4	20.5	7.3	20.8	0.0	139.8	
Shaqlawa -16	GW10	Spring	0.25	7.4	593	385.45	193	251	36	39.2	1.75	0.2	10	14	15	0	118.9	17.21
		Summer	0.3	7.2	618	401.7	190	290	38	47.5	3	0.4	20	6	27	0	126.9	16.93
		Autumn	0.37	7.2	638	414.7	198	311	45	48.4	1.2	0.5	18	10	40	0	133.3	17.52
		Winter	0.1	7.6	625	406.25	200	260	48	34.2	1	0.3	12	3	19	0	124.3	16.69
Shaqlawa -13	GW11	Spring	7.6	7.3	831	540.15	320	450	48	80.3	18	0.9	82	9	47	0	187.8	47.52
		Summer	2.8	7.6	684	444.6	264	293	51	40.4	3.14	0.5	22	9	28	0	142.3	28.03
		Autumn	2	7.9	662	430.3	237	311	54	42.9	3.75	0.6	26	11	32	0	140.0	25.54
		Winter	0.1	7.8	535	347.75	200	260	48	34.2	1	0.3	12	3	18	0	112.9	17.00
Mean			3.13	8	678	441	255	329	50	49	6	1	36	8.0	31	0	146	
Shaqlawa -20	GW12	Spring	2.3	7.3	597	388.05	220	280	45	40.8	2.8	0.6	15	4.1	27	0	125.4	25.10
		Summer	0.6	7.5	538	349.7	241	289	49	40.6	2.2	0.5	14	18	25	0	121.2	19.23
		Autumn	0.87	7.5	545	354.25	249	314	51	45.5	1.8	0.7	19	21	16	0	125.0	20.57
		Winter	0.1	7.6	555	360.75	150	280	56	34.2	2	0.3	13	4	20	0	114.1	16.72
Mean			0.97	7.5	558.8	363.2	215.0	290.8	50.3	40.3	2.2	0.5	15.3	11.8	22.0	0.0	121.4	
Mean			1.0	7.6	689.3	448.0	278.5	311.5	57.4	41.2	22.8	1.0	42.1	11.9	72.7	0.4		
SD			1.5	0.4	354.2	230.2	117.4	91.7	26.7	17.8	57.0	1.3	96.3	9.9	71.6	2.4		

Table 2: Correlations between studied samples and sites

Correlation		Turbidity	pH	EC	TDS	Alkalinity	Hardness	Ca	Mg	Na	K	Cl	NO_3	SO_4	MPN
Turbidity	Pearson Correlation	1	-.088	.049	.049	.079	.059	-.048	.110	-.004	.008	.075	.001	-.104	.447**
	Sig. (2-tailed)		.551	.739	.739	.594	.690	.744	.458	.980	.955	.614	.995	.483	.002
	N	48	48	48	48	48	48	48	48	48	48	48	48	48	47
pH	Pearson Correlation	-.088	1	.448**	.448**	.564**	.250	.070	.235	.491**	.461**	.407**	.065	.527**	.101
	Sig. (2-tailed)	.551		.001	.001	.000	.086	.637	.107	.000	.001	.004	.659	.000	.497
	N	48	48	48	48	48	48	48	48	48	48	48	48	48	47
EC	Pearson Correlation	.049	.448**	1	1.000**	.762**	.291*	-.046	.399**	.905**	.870**	.929**	.283	.538**	-.087
	Sig. (2-tailed)	.739	.001		.000	.000	.045	.758	.005	.000	.000	.000	.051	.000	.559
	N	48	48	48	48	48	48	48	48	48	48	48	48	48	47
TDS	Pearson Correlation	.049	.448**	1.000**	1	.762**	.291*	-.046	.399**	.905**	.870**	.929**	.283	.538**	-.087
	Sig. (2-tailed)	.739	.001	.000		.000	.045	.758	.005	.000	.000	.000	.051	.000	.559
	N	48	48	48	48	48	48	48	48	48	48	48	48	48	47
Alkalinity	Pearson Correlation	.079	.564**	.762**	.762**	1	.181	-.037	.254	.837**	.794**	.783**	.115	.430**	-.025
	Sig. (2-tailed)	.594	.000	.000	.000		.218	.803	.082	.000	.000	.000	.435	.002	.867
	N	48	48	48	48	48	48	48	48	48	48	48	48	48	47
Hardness	Pearson Correlation	.059	.250	.291*	.291*	.181	1	.589**	.695**	.080	.187	.073	.331*	.414**	-.026
	Sig. (2-tailed)	.690	.086	.045	.045	.218		.000	.000	.590	.202	.624	.021	.003	.862
	N	48	48	48	48	48	48	48	48	48	48	48	48	48	47
Ca	Pearson Correlation	-.048	.070	-.046	-.046	-.037	.589**	1	-.168	-.176	-.001	-.136	.247	-.019	.185
	Sig. (2-tailed)	.744	.637	.758	.758	.803	.000		.253	.231	.997	.358	.090	.899	.213
	N	48	48	48	48	48	48	48	48	48	48	48	48	48	47
Mg	Pearson Correlation	.110	.235	.399**	.399**	.254	.695**	-.168	1	.255	.230	.210	.200	.531**	-.204
	Sig. (2-tailed)	.458	.107	.005	.005	.082	.000	.253		.080	.115	.151	.172	.000	.170
	N	48	48	48	48	48	48	48	48	48	48	48	48	48	47
Na	Pearson Correlation	-.004	.491**	.905**	.905**	.837**	.080	-.176	.255	1	.939**	.945**	.172	.581**	-.048
	Sig. (2-tailed)	.980	.000	.000	.000	.000	.590	.231	.080		.000	.000	.243	.000	.749
	N	48	48	48	48	48	48	48	48	48	48	48	48	48	47
K	Pearson Correlation	.008	.461**	.870**	.870**	.794**	.187	-.001	.230	.939**	1	.898**	.320*	.559**	-.022
	Sig. (2-tailed)	.955	.001	.000	.000	.000	.202	.997	.115	.000		.000	.027	.000	.886
	N	48	48	48	48	48	48	48	48	48	48	48	48	48	47
Cl	Pearson Correlation	.075	.407**	.929**	.929**	.783**	.073	-.136	.210	.945**	.898**	1	.129	.469**	-.042
	Sig. (2-tailed)	.614	.004	.000	.000	.000	.624	.358	.151	.000	.000		.383	.001	.777
	N	48	48	48	48	48	48	48	48	48	48	48	48	48	47
NO_3	Pearson Correlation	.001	.065	.283	.283	.115	.331*	.247	.200	.172	.320*	.129	1	.346*	.015
	Sig. (2-tailed)	.995	.659	.051	.051	.435	.021	.090	.172	.243	.027	.383		.016	.920
	N	48	48	48	48	48	48	48	48	48	48	48	48	48	47
SO_4	Pearson Correlation	-.104	.527**	.538**	.538**	.430**	.414**	-.019	.531**	.581**	.559**	.469**	.346*	1	-.023
	Sig. (2-tailed)	.483	.000	.000	.000	.002	.003	.899	.000	.000	.000	.001	.016		.881
	N	48	48	48	48	48	48	48	48	48	48	48	48	48	47
MPN	Pearson Correlation	.447**	.101	-.087	-.087	-.025	-.026	.185	-.204	-.048	-.022	-.042	.015	-.023	1
	Sig. (2-tailed)	.002	.497	.559	.559	.867	.862	.213	.170	.749	.886	.777	.920	.881	
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 3. Water quality classification ranges and types of water based on WQI values

No.	Type of groundwater	Range
1	Excellent water	< 50
2	Good water	50.1–100
3	Poor Water	100.1–200
4	Very poor water	200.1–300
5	Unsuitable for drinking/Human consumption purpose	≥ 300.1

4. CONCLUSIONS

4.1 Conclusions:

1. Our conclusion of the present study revealed that the quality assessment of physico-chemical parameters obtained not exceeded and in compliance with permissible limits recommended by WHO Standards and remain in the safe side and considered suitable for drinking consumption.
2. Total alkalinity and Total hardness in studied samples were high due to the geological formation of the area.
3. Studied water samples were satisfactory for drinking purpose physically and chemically except at GW7 during winter and spring season
4. Bacteriologically, water wells were satisfied for drinking except GW1 during winter 2016.
5. Water quality index for studied water samples are excellent and at safe values for drinking purpose.

4.2 Recommendations

1. Monitoring of artesian wells should be done in regular state at least quarterly by government.
2. Chlorination of water is of great important.

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