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Assessment of Spring Water Quality Around Safeen Mountain Area in Iraqi Kurdistan region

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ABSTRACT

The water quality index (WQI) was applied in 10 springs within Erbil governorate, Kurdistan region, in order to certain the quality of water for public consumption. In this study, water quality index was determined based on sixteen Physico-chemical parameters like pH, electrical conductivity, total dissolved solids, turbidity, total alkalinity, total hardness, sulfate, chloride, nitrite, nitrate, calcium, magnesium, sodium, potassium, dissolved oxygen, and biochemical oxygen demand. The relative weight assigned to each parameter ranged from 1 to 5, based on the important parameters for aquatic life and drinking purposes. Because water quality index is one of the most effective tools to communicate information on the quality of water to the concerned citizen and policymakers. The results indicated that the water quality of the springs is good except for site 3 and 9 are poor.

Kewords: Spring water, Water Quality Index

1. Introduction

Water is a prime natural resource [1], is an essential requirement of human life and activities associated with the industry, agriculture, and others, and it considers one of the most delicate parts of the environment [2]. Kurdistan is rich in surface and underground water and has a lot of rivers and springs [3]. Spring is one of the forms of a natural outflow of groundwater onto the surface of the earth. It is a link connecting the underground and the surface parts of the water circulation system. Springs are occurring throughout the landscape and vary greatly in morphology and size [4]. They play an important role in terms of public health, economics, agriculture, tourism, and other human activities.

Water quality is considered an important factor to judge environmental changes that are strongly associated with social and economic development [5]. In addition, the suitability of water sources for human consumption has been described in terms of the water quality index (WQI), which is one of the most effective ways to describe the quality of water [6]. The water quality index (WQI) provides a single number that expresses the overall water quality at a certain location and time based on several water quality parameters. The objective of WQI is to turn complex water quality data into information that is understandable and usable by the public [7]. this study was carried out to evaluate and assess water quality and its suitability for drinking purposes by using WQI.

2. Material and Methods

2.1 Description of the study area

Safeen Mountain is located about 30 kilometers northeast Erbil city. Its length is nearly 65km, and its height reaches about 1960 m a.s.l. It is as asymmetrical anticline, plunging toward North West. Safeen Mountain represents the core of anticline; consisting of limestone and dolostone of Bekhme and Qumchuqa. To the south westward of Safeen, there are other mountains such as Shafi spi, Mizquata, Nawdari, and Sararish. Their elevations range from 1019 to 1429 m above sea level. The peak of them is composed of well-bedded partly dolomitized limestones that are highly resistant to erosion.

In this study, 10 spring sites to be sampled are presented in Table (1) and figure (1), within Erbil governorate as follows: sites 1,2,3,4,5,6,9 and 10 are located in Shaqlawa district, while sites 7 and 8 are located in Koya district.

The Erbil province is the capital of Kurdistan located between the latitude of 35o 40’ and 30o 30’ N, and longitude of 43o20’ and 44o20’ E. Shaqlawa district is part of the Erbil Governorate of Iraq in the Kurdistan region, lies 51 km to the northeast of Erbil, at the bottom of Safeen Mountain. Shaqlawa is situated between Safeen Mountain and Sork Mountain, sits 1066 m above sea level, and is sub-divided into five sub-districts, namely; Salahaddin, Harir, Hiran, Balisn, and Basirma, and it has 210 villages. Shaqlawa shares borders with Swran districts to the north, Dashty Hawler district to the south, Dohuk governorate to the west, and Suleimaniah governorate and Koya district to the east [8].

Koya district is located in the east of Erbil; sub–divided into five sub-districts (Taq taq, Shoresh, Ashti, Sktan, and Segrdkan). Koya City eliminated a height of 620 m above sea level. The district is bordered from the east and south by the lesser Zab River and from the northeast by Hebat Sultan Mountain, from the west by Bawaji Mountain. The mountainous area is located north of Koya, while in the south and southwest, a fertility plain extends to the border of Erbil with Kirkuk city, which represents the historical alluvial plain of the Tigris River [9].

2.2 Laboratory Analysis

To determine the water quality index, Water samples were collected from ten spring sites around the Safeen mountain area at monthly intervals from September 2014 and extended to June 2015; water samples were taken at each site for physical and chemical analysis using polyethylene bottles which had been rinsed twice with water samples before filling.

Table 1: location and elevation of the sampling sites.

Sites	locality	Latitude	longitude	Elev (m)
1	Jneran Spring	36°2207.3 N	44°2311.3E	940
2	Aqubani Saru spring	36°2041.4 N	44°2432.4E	994
3	Kani Piawan	36°2116.4 N	44°2527.9E	900
4	Kani Zhnan	36°2117.1 N	44°2529.0E	911
5	Kani Masihiakan	36°2038.8 N	44°2606.5E	916
6	Kani Mam Hawez	36°1748.7N	44°2831.8E	904
7	Smaquli Saruchawa spring	36°1404.6 N	44°3009.0E	896
8	Kani Mam Hussain	36°1130.2 N	44°3133.7E	793
9	Kani Ziarat	36°1703.2 N	44°2352.6E	927
10	Kani Shekh	36°1727.2 N	44°2337.8E	980

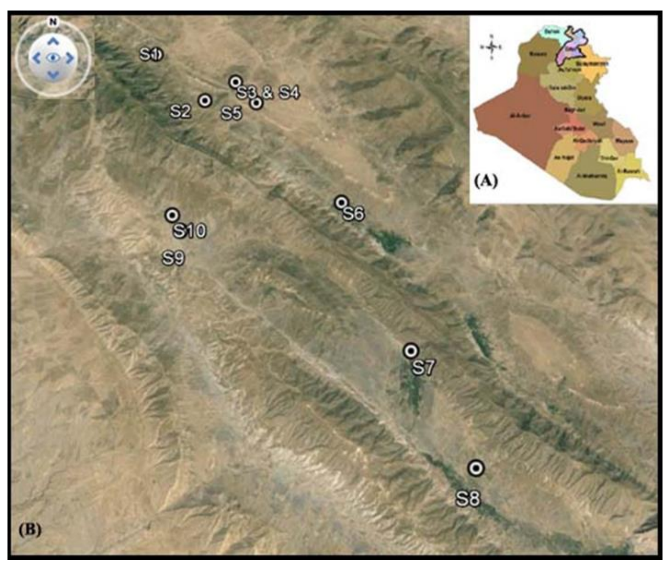

Figure 1: Map of A - Iraq. B - Studied sites from (Google Earth 2016).

The samples were analyzed as per standard methods for fourteen Physico-Chemical parameters namely; pH (Hydrogen ion concentration), EC (Electrical conductivity), (DO) (Dissolved oxygen), BOD (Biochemical oxygen demand), turbidity, TA (Total alkalinity), TH (Total hardness), ions of Ca2+ (Calcium), Mg2+ (Magnesium), Na+ (sodium), K+ (potassium), NO3 - (nitrate), NO2 (nitrite) and PO4(phosphate). But the analysis of the parameters for chloride and sulfate according to (10), Total dissolved solids were determined according to the method given by [11], Sodium adsorption ratio (SAR) was estimated by the equation described by [12]. The dissolved oxygen, electrical conductivity, and pH were estimated on the spot at the time of sampling.

2.3. Application of WQI

In this study, for the calculation of the water quality index, sixteen important parameters were chosen and using drinking water quality standards [13] throughout three steps:

In the first step, each of the sixteen parameters has been assigned a weight (AWi) ranging from (1 to 5) according to its relative importance in the overall quality of water for drinking purposes, based on [14].

However, assigned a weight of 1 was considered as the least significant and 5 as the most significant,

In the second step, the relative weight (Rw) was calculated by using the following equation:

$$Rw = \frac{AWi}{\sum_{i-1}^{n} Awi} \quad (1)$$

Where: Rw is the relative weight; AW is the assigned weight of each parameter, and n is the number of parameters.

In the third step, a quality rating scale (Qi) for all of the parameters except pH and DO was assigned by dividing the concentration in each water sample by its respective standard according to the drinking water guideline recommended by the [13], the results were then multiplied by 100.

$$Qi = \frac{Ci}{Si} \times 100 \quad (2)$$

While the quality rating for pH and DO (QpH and QDO) was calculated based on the following equation:

$$QpH \text{ and } QDO = \frac{Ci - Vi}{Si - Vi} \times 100 \quad (3)$$

Where:

Qi is the quality rating, Ci is the value of the water quality parameter obtained from the laboratory analysis, Si is the value of the water quality parameter obtained from WHO [13], and Vi is the ideal value which is considered as 7 for pH and 14.6 for DO Table 2.

Finally, the overall Water Quality Index was calculated by aggregating the quality rating with the value of relative weight linearly then the water quality was classified according to [15].

$$WQI = \sum Qi\, Rw \quad (4)$$

Table 2: Calculation of WQI for drinking purpose for studied sites

Parameters	Unit	WQS	Wi	RW	Qi
Turbidity	NTU	5	3	AWi/∑AWi	Ci/Si×100
DO	mg/L	5	4	AWi/∑AWi	(Ci-Vi)/(Si-Vi)×100
BOD	mg/L	5	3	AWi/∑AWi	Ci/Si×100
pH		6.5-8.5	4	AWi/∑AWi	(Ci-Vi)/(Si-Vi)×100
Ec	µS/cm	1000	3	AWi/∑AWi	Ci/Si×100
TDS	mg/L	500	3	AWi/∑AWi	Ci/Si×100
T. Alkalinity	mgCaCO₃/L	200	1	AWi/∑AWi	Ci/Si×100
T. Hardness	mgCaCO₃/L	200	2	AWi/∑AWi	Ci/Si×100
Calcium	mg/L	100	2	AWi/∑AWi	Ci/Si×100
Magnesium	mg/L	30	2	AWi/∑AWi	Ci/Si×100
Sodium	mg/L	200	1	AWi/∑AWi	Ci/Si×100
Potassium	mg/L	10	1	AWi/∑AWi	Ci/Si×100
Chloride	mg/L	250	2	AWi/∑AWi	Ci/Si×100
Nitrite	mg/L	3	2	AWi/∑AWi	Ci/Si×100
Nitrate	mg/L	50	5	AWi/∑AWi	Ci/Si×100
Sulfate	mg/L	250	4	AWi/∑AWi	Ci/Si×100

Table 3: Range of WQI and type of water quality as suggested by (15).

Range	Type of water
< 50	Excellent water
50 – 100	Good water
100.1 – 200	Poor water
200.1 – 300	Very poor water
> 300	Water unsuitable for drinking purposes

3. Results and Discussion

3.1 Physiochemical parameters

Temperature is an important parameter that not only impacts the external behavior of living organisms but also influences the internal Physico-chemical milieu organism and can drastically change or influence the whole course of metabolic process within the physiological process within the ecosystem [16]. Most biological activity occurs when the water temperature is between 10 - 30°C [17]. The highest mean value of phosphorus (PO_4^{-3}) was 17.7 observed in September while the minimum mean value was 15.45 in February.

EC is the measure of cations and anions in water samples and shows the concentration of dissolved salts which to contributes the prediction of water quality [18]. And it is used indirectly to determine the total dissolved solids in a water sample [19], the highest mean value was determined at Site 9 may be related to a high concentration of sodium, chloride, and TDS at this site. Furthermore, the water samples of site 9 were found to be more turbid than the other sites.

The results of pH value in spring water from Table 4 varied from 7.46 to 8.83, indicating that the water sample is almost neutral to sub alkaline in nature. In the Kurdistan region of Iraq the pH of water is characterized by a shift towards the alkaline side of neutrality, due to the geological formation of the area, which is composed mainly of $CaCO_3$ (20), this may be related to the soil and watershed characters of the mountain area. The minimum mean value of total alkalinity was 238.3 mg $CaCO_3.l^{-1}$, while the maximum mean value was 362.2 mg $CaCO_3.l^{-1}$. Total hardness was between 176.9 mg $CaCO_3.l^{-1}$ and 521 mg $CaCO_3.l^{-1}$.

On the other hand, results of major cations and anions revealed the following records: calcium, magnesium, sodium and potassium were ranged between 42.6 – 129.1 $mg.l^{-1}$, 16.5 – 47.5 $mg.l^{-1}$, 4.194 – 165.5 $mg.l^{-1}$ and 0.508 – 1.246.98 $mg.l^{-1}$. Chloride ranged from 8.7 – 52.1 $mg.l^{-1}$, sulphate ranged from 740.9 – 783.3 mg $SO_4.l^{-1}$. The SAR values ranged from 0.105 to 3.08 $meq.l^{-1}$ with an average value of 1.03 $meq.l^{-1}$ Based on the sodium adsorption ratio (SAR) all water resources were excellent for irrigation purposes.

The concentration of nitrite, nitrate and reactive phosphorus were ranged from 0.094 to 1.55 µg NO_2 - $N.l^{-1}$, 2.357 to 32.68 mg NO_3 - $N.l^{-1}$ and 0.34 to .72 µg PO_4 - $P.l^{-1}$ respectively. Of DO and BOD_5 levels changed from 2.8 to 8.78 mg. l^{-1} and 0.52 to 2.24 mg. l^{-1}.

3.2. Water quality index

The values of various physicochemical parameters for the calculation of the water quality index are present in Table 4. While the results of the computed WQI values of the spring water resources obtained from this study are shown in Table 6. It is ranged from 80.55 to 128.03. And therefore can be categorized into two types, good water quality, and poor water quality. The water quality status for almost all spring sites fall under the good category, the results are supported by Aziz and Abdulwahid (21), who indicated that the water characteristics or quality of Kurdistan are either better or equal to the waters of the most of part of the world, which are potable and suitable after conventional treatments for different uses. While, sites 3 and 9 fall under the poor category, this is maybe due to the effect of agricultural activity, also higher values of turbidity, pH, TDS, and EC were found at these sites.

Table 6: Water Quality Index (WQI) for drinking purposes in the studied sites

Sites	WQI	Water Quality Status
1	87.64	Good
2	89.32	Good
3	101.30	Poor
4	84.40	Good
5	80.69	Good
6	93.69	Good
7	80.87	Good
8	99.95	Good
9	128.03	Poor
10	80.55	Good

Table 4: Means for physico-chemical parameters for the study sites.

Sites	Water temp. ˚C	EC µS.cm^{-1}	TDS mg.cm^{-1}	Turbidity NTU	pH	T. Alkalinity mg $CaCO_3$.l^{-1}	T. Hardness mg $CaCO_3$.l^{-1}	Ca mg.l^{-1}	Mg mg.l^{-1}	Na mg.l^{-1}
1	15.15	576.6	369	3.81	7.49	303.5	373.7	87.2	37.9	13.09
2	16	550.2	352.1	3.94	7.65	321.9	355.6	88.7	32.1	5.818
3	16.35	745.6	477.2	5.14	7.54	240.3	521	129.1	47.5	11.52
4	16	609.7	390.2	0.46	7.46	283.1	401.3	100.9	36.4	10.83
5	15.98	528.2	338	0.32	7.5	300.1	320	65	37.7	14.57
6	15.96	669.7	428.6	4.54	8.66	362.2	176.9	42.6	16.5	165.5
7	17.03	550	352	2.04	7.65	261.7	298.4	67.9	31.4	4.194
8	16.52	518.2	331.7	3.2	8.11	238.3	325.4	73.7	33.9	8.961
9	16.56	820.8	525.3	17.8	8.83	346.6	320.2	55.3	43.3	121.3
10	16.9	508.1	325.2	0.72	7.65	311.7	341.2	76.3	36.1	7.262
LSD	0.55	45.84	29.33	1.55	0.10	23.53	24.41	11.19	5.67	20.36

Sites	K mg.l^{-1}	Cl mg.l^{-1}	SO_4 mg.l^{-1}	SAR meq.l^{-1}	NO_2 µg.l^{-1}	NO_3 mg.l^{-1}	PO_4 µg.l^{-1}	DO mg.l^{-1}	BOD mg.l^{-1}
1	0.665	17.6	759.2	0.293	0.168	20.89	0.37	5.49	1.13
2	0.508	13.8	749.7	0.136	0.355	32.68	0.35	6.88	1.34
3	0.925	18.4	783.3	0.22	0.171	25.52	0.35	6.1	1.68
4	0.86	16	767	0.236	0.262	24.79	0.46	5.6	0.58
5	1.025	22.5	749	0.355	0.155	26.45	0.43	5.3	0.52
6	1.246	20.8	780.6	5.492	0.566	2.357	0.72	2.8	1.23
7	0.885	9.6	747.6	0.105	0.428	14.67	0.34	4.6	0.95
8	0.623	23.6	776.3	0.219	1.19	71.6	0.44	8.87	1.4
9	4.96	52.1	771.6	3.08	1.557	20.69	0.52	7.6	2.24
10	0.575	8.7	740.9	0.171	0.094	20.62	0.6	5.35	0.71
LSD	0.54	5.55		0.628	0.13	4.33	0.17	0.65	0.29

Table 5: Means for physico-chemical parameters during the studied months.

Month	Water temp. °C	EC µS.cm^{-1}	TDS mg.l^{-1}	Turbidity NTU	pH	T. Alkalinity mg $CaCO_3$.l^{-1}	T. Hardness mg$CaCO_3$.l^{-1}	Ca mg.l^{-1}	Mg mg.l^{-1}
Sep.	17.7	570.1	364.9	5.54	7.84	266.4	283.3	63.5	29.7
Oct.	16.87	582.4	372.7	5.47	7.97	268.8	309.7	68.6	34.2
Nov.	16.45	615.5	393.9	4.66	7.99	303.8	299.7	65.9	32.3
Dec.	15.77	554.3	354.6	3.82	7.92	314.5	365.8	86.9	35.9
Jan.	15.52	544.2	348.3	3.36	7.78	303.5	385.3	87.9	39.8
Feb.	15.45	544.3	348.4	3.53	7.69	301.3	385.6	86.8	39.9
Mar.	15.95	606.7	388.3	4.4	7.81	303	352.4	88.2	31.7
Apr.	16.05	626.4	400.9	5.3	7.79	304.5	353.6	84.1	34.2
May	16.2	681.7	436.3	2.74	7.87	306.6	348 .0	79.3	36.1
Jun.	16.49	751.5	481	3.11	7.88	297	350.3	75.5	39

Month	Na mg.l^{-1}	K mg.l^{-1}	Cl mg.l^{-1}	SO_4 mg.l^{-1}	SAR meq.l^{-1}	NO_2 µg.l^{-1}	NO_3 mg.l^{-1}	PO_4 µg.l^{-1}	DO mg.l^{-1}	BOD mg.l^{-1}
Sep.	48.49	1.778	28.7	755.6	1.499	0.507	25.197	0.37	6.16	1.34
Oct.	44.65	1.679	27.7	766.6	1.232	0.510	27.162	0.31	5.95	1.49
Nov.	42.49	1.510	22.3	748.0	1.317	0.559	26.461	0.16	6.16	1.46
Dec.	30.28	1.132	19.1	763.8	0.852	0.608	27.969	0.14	6.10	1.39
Jan.	30.31	1.016	18.0	776.3	0.805	0.639	29.082	0.41	6.41	1.13
Feb.	30.47	1.006	17.9	775.9	0.792	0.536	29.368	0.86	6.35	1.02
Mar.	33.20	0.984	17.6	765.7	0.906	0.451	26.668	0.87	5.79	0.92
Apr.	33.7.0	1.007	16.9	761.2	0.929	0.414	24.414	0.66	5.52	0.95
May	33.93	0.993	17.1	754.0	0.968	0.365	22.734	0.46	5.22	0.94
Jun.	35.55	1.17	17.6	758.1	1.014	0.358	21.219	0.33	4.99	1.13

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