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The Variations in Water Characteristics along the Komel River, Northeastern Iraq

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ABSTRACT

The majority of spring water from the limestone layers near the surface is suitable for various domestic, agricultural, and industrial uses and typically requires minimal purification. The springs from the highland areas of Zawitah, Baidol, Belkev, Atrush, and Khans converge to form the Komel River, the largest tributary of the Al-Khazer River. The Komel River flows along the right side of Mount Bardrash. The rainfall and snow accumulation in the Komel River basin, particularly in the hilly areas, contribute to its spring water sources. The physical and chemical characteristics of the water were assessed using the water quality index (WQI), in accordance with the WHO standard values. Generally, the water is suitable for irrigation, as indicated by the sodium adsorption ratio (SAR) values, which suggest that the water is low in sodic content and classified as Class S1. Additionally, the sodium percentage (SSP) is less than 75%, the magnesium adsorption ratio (MAR) is below 50%, and the residual sodium carbonate (RSBC) values are less than 1.25. These indicators reflect low calcium and magnesium bicarbonate sedimentation from irrigation water and minimal sodium concentration increases, reducing the risk of soil damage. The permeability index (PI) classifies the water as suitable for irrigation (Class II), and the Kelly's ratio (KR) values are below 1.0. The study concludes that the water quality of the Komel River is comparable to spring water, making it suitable for both domestic and agricultural use. This supports the establishment of water harvesting operations in the secondary valleys of the Komel River basin, particularly in the hilly regions. Additionally, irrigation projects can be developed in the downstream plain areas due to the favorable topographic slope.

INTRODUCTION

Humans rely on spring water as one of the most significant sources for drinking water primarily because it frequently has good quality and hardly ever requires processing for filtration and purification to make it suitable for domestic, agricultural, and industrial uses **(Awadh & Al-Ghani, 2014; Al-Hamdani *et al*., 2016; Awadh *et al*., 2021)**. The spring water often flows out naturally through fissures and cracks as a result of the movement of water in the stored rocks **(Boschetti *et al*., 2018; Medler & Eldridge, 2021)** that are exposed to permanent or seasonal feeding from rainwater or snow melting. The number of springs is influenced by the amount of rainfall, the topography, and the types of rocks through which the water flows **(Meuli & Wehrle, 2001; Basavaraja *et al*., 2011; Leizou *et al*., 2017; Aqrawi & Al-Mallah, 2021)**. The quality of spring water depends on the degree of interaction between rainwater runoff and surface water movement, the types of rocks and soil passing by and seeping into the storing layers, and the types of minerals that can interact with water **(Awadh & Ahmed, 2013)**. Consequently, the domestic and agricultural activities have an impact on the quality of seep water and how it mixes with groundwater near the surface, which is reflected in the region's spring water quality **(Dikeogu *et al*., 2018)**.

The Komel River follows the slope of the area and is consistent with the direction of the folds **(Jabir, 2020)** since it flows from the northern areas toward the south and southeast (Fig. 1). The Komel River is one of the largest tributaries of the Al-Khazer River (the largest tributary of the Greater Zap River) and meets from the right side near Mount Bardarsh **(Jassas & Merkel, 2014)**.

The study area is located within the Mediterranean climate, and the areas of the Komel River springs are characterized as a mountainous area at a height of more than 1500 m.a.s.l. **(Hamrawi & Ibrahim, 2021)**. Moreover, it has 600-800mm of annual rainfall during the winter and spring **(Aziz *et al*., 2020; Hamrawi and Ibrahim, 2021)** in addition to the mountainous regions' annual snowfall, all of which serve as a source of water for the springs. These mountainous areas occupy the northern and northeastern part of the basin, which represents the high folding zone, while the other portion, which lies to the south and is part of the low fold's zone, is an undulating plateau area with a height of 400–500 meters that slopes down to the Al-Khazer River **(Asaad & Balaky, 2021; Hamrawi & Ibrahim, 2021)**. Therefore, tectonic and geodynamic effects, as well as the type of exposed rocks and climatic conditions are the main factors that control geomorphological features in high folded zone **(Sissakian *et al*., 2014)**.

The formations that are exposed in the high folded zone part of the area are: Shiranish Fm (Upper Cretaceous): consists of thinly well-bedded marly and chalky limestone, Kolosh Fm (Paleocene): it consists of black shale, claystone, sandstone, and siltstone; some very thin layers of limestone. Gercus Fm (Paleocene-Lower Eocene): consisting of red claystone, sandstone, and siltstone, and very thin layers of limestone, and gypsum. Pila Spi Fm (Eocene): it consists of well-bedded dolostones **(Ghafur *et al*., 2019)**. In the low folded zone part of the studies area; the formations exposed are Fat'ha Fm. (middle Miocene): consists of cycles of gypsum, marl and limestone, Injana Fm (Upper Miocene): consist of cycles of sandstone, siltstone and claystone, Miqdadya Fm (Upper Miocene): it consists of a sequence of gravel, sand, and claystone, and Bai Hassan Fm. (Pliocene): is mainly formed of massive conglomerate and coarse river deposits **(Sissakian & Al-Jiburi, 2014)**.

The quaternary deposits are composed of river sediment deposited during periods of flood, and slope deposits at the foot of mountains, they are usually thick and wide in the main valley regions depending on the geomorphology of the region **(Al-Jiburi & Al-Basrawi, 2012)**.

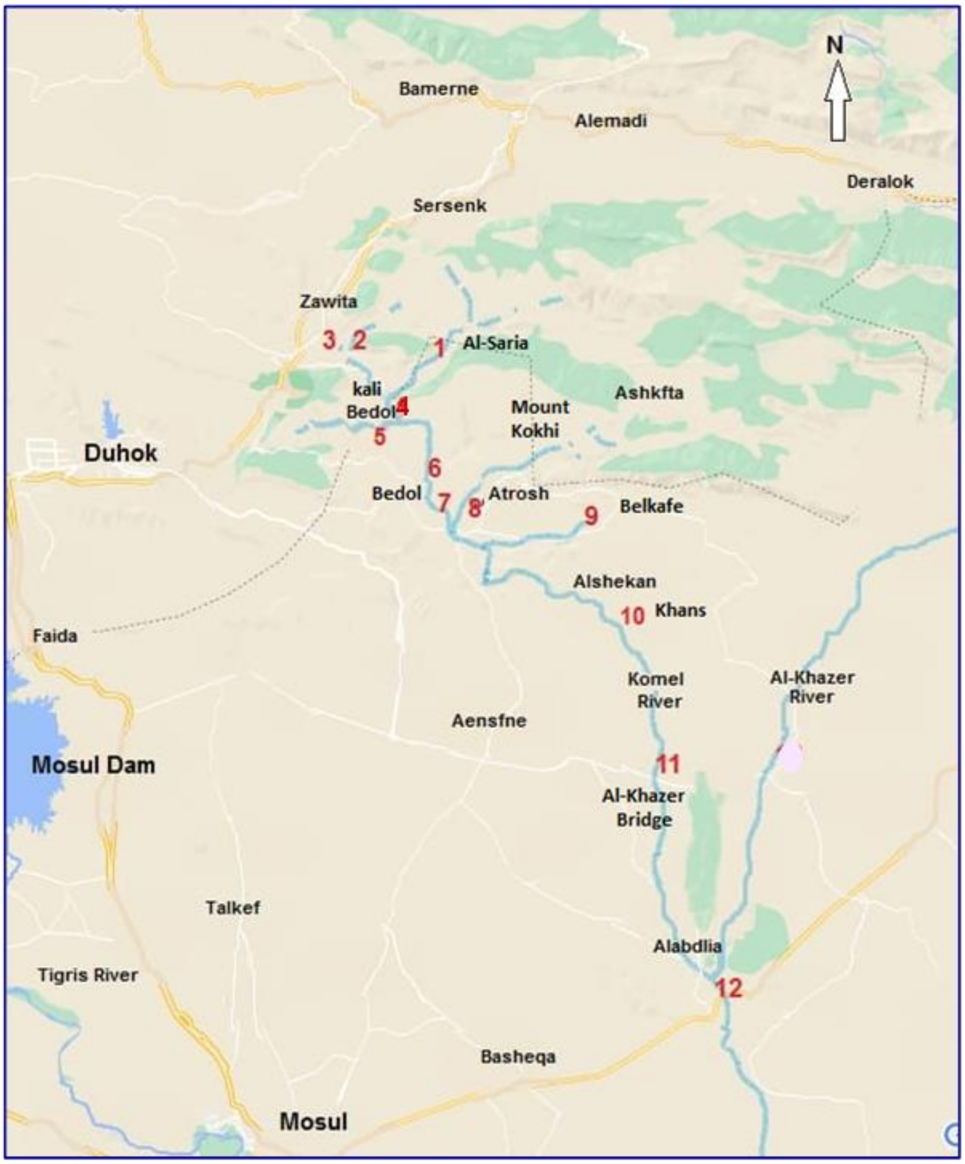

Fig. 1. Location map of water samples in the studied area.

The Komel basin's morphometric characteristics were studied by **Jabir (2020)**, who found that the northern regions of the basin contain many (first and second) orders that meet in the valleys. The basin is also distinguished by the dominance of the impact of hard rocks versus the decrease in the impact of sedimentary content, and the valleys are enlarging with the decline toward the south and southeast due to the topography of the area. According to **Aqrawi and Al-Mallah (2021)**, spring water is generally good to excellent for drinking since it is related to seeped surface water and has no relationship with groundwater. As a result, the water is of the type with temporary hardness brought on by the effect of bicarbonate, calcium, and magnesium that are produced from the solubility of carbonate. **Al-Youzbakey and Sulaiman (2021)** assessed the water quality of the Khazer-Komel River and stated that it was suitable for drinking, domestic, and agricultural uses. They also stated that the water quality of the Al-Khazer -Komel River has no effect on the water quality of the Greater Zab River after meeting.

The aim of the study was to evaluate spring waters and their impact on the Komel River's water quality and use.

MATERIALS AND METHODS

Twelve samples were taken from the major tributaries that feed into the Komel River. (1): the stream of water collection from Al-Saria springs, (2) and (3): the stream of water springs collection at the south of Mount Zawita, (4): the stream of water springs collection before the Bedol region, (5): Kali Bedol, (6) and (7): Wadi Bedol, (8): Atrosh springs near the southern side of Mount Kokhi, (9): the main stream of Belkafe springs (10): at Khans area, (11): Kaziz Bridge near Mahed complex and (12): Al-Abdaliya area before the Komel River meets the Al-Khazer River (Fig. 1).

The acidic function (pH) and electrical conductivity (EC) were measured in field using the portable EC type (hold/3meter). TDS and turbidity were measured in laboratory. Standard chemical methods were used to estimate the concentrations of cations and anions **(Abbawi & Hassan, 1990)**. TH, calcium, magnesium, bicarbonate and chloride were measured by titration methods; sulfate and nitrate via colorimetric methods using the the UV- spectrophoto-meter type - OGAWA, OSK 7724), sodium and potassium were evaluated by the flame photometer, type- JENWAY PEP7). Laboratory analyses were performed at the "Geochemistry" Laboratory at Dams and Water Resources Research Center – University of Mosul. All samples were tested as duplicate samples.

The water quality index (WQI) provides a comprehensive assessment of water quality by condensing multiple water quality parameters into a single value. This allows for the evaluation and management of various water uses, such as domestic, agricultural, and industrial applications, in a more streamlined and integrated manner **(Kachroud *et al*., 2019; Beg *et al*., 2021)**. WQI was calculated using physical (pH, EC, TDS and TH) and chemical parameters (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^-, SO_4^{2-}, Cl^- and NO_3^-) compared to the WHO standard values **(WHO, 2006)** using the equation of **Gupta and Misra (2016)**.

$$WQI = \sum Qi * Wi / \sum Wi \quad \text{……………………… (1)}$$

Qi = Qualitative evaluation for each parameter. (Qi = 100 * (Vm– Vi) / (Vs – Vi))

Vm= the measured value of the parameter from the chemical analysis samples.

Vi = theoretical value of the parameter is taken from the standard table,and its value is (0) for all parameters except (pH= 7).

Vs = standard values for the parameter according to the standards of the World Health Organization (WHO, 2006) for drinking water (Table 1).

Wi = K / Vs ; Wi = Relative weight for the parameter; (K = 1). (Appendixes 1~4).

Table 1. The standard values for the parameter according to the standards of the World Health Organization **(WHO, 2006)** for drinking water

pH	EC	TDS	TH	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^-	SO_4^{2-}	Cl^-	NO_3^-
8.5	1400	1000	500	75	50	200	55	400	400	250	50

The water balance was calculated based on the concentrations of cations and anions in *meq/ l*, reflecting the accuracy of chemical analysis data, in addition to using the values in *meq/ l* to estimate the water classification parameters for irrigation purposes such as: sodium adsorption ratio (*SAR*), sodium percentage (*SSP*), amount of residual sodium carbonate (*RSC*), magnesium adsorption ratio (*MAR*), the permeability index (*PI*) and Kelly's ratio (*KR*) **(Leizou *et al.*, 2017)**:

$$SAR = Na^+ / \sqrt{[(Ca^{2+} + Mg^{2+})/2]} \quad \text{……………….….……….…….. (2)}$$

$$SSP = Na^+ \, X \, 100 / (Ca^{2+} + Mg^{2+} + Na^+ + K^+) \quad \text{……………….……… (3)}$$

$$RSC = (CO_3^{=} + HCO_3^-) - (Ca^{2+} + Mg^{2+}) \quad \text{……………….…...….……. (4)}$$

$$MAR = Mg^{2+} \, X \, 100 / (Ca^{2+} + Mg^{2+}) \quad \text{…………………………..…… (5)}$$

$$PI = (Na^+ + \sqrt{HCO_3^-}) / (Ca^{2+} + Mg^{2+} + Na^+) \, X \, 100\% \quad \text{……..… (6)}$$

$$KR = Na^+ / (Ca^{2+} + Mg^{2+}) \quad \text{……………………………………….….. (7)}$$

RESULTS AND DISCUSSION

Table (2) indicates that the most concentrated anion in the water is bicarbonate, with values ranging from 184 to 216 mg/l, averaging 202.1mg/ l. This high concentration is attributed to the solubility of carbonate minerals, such as calcite, which are present in the limestone and marly limestone of the Shiranish, Kolosh, and Pila Spi formations, as well as in the thin layers within the Gercus Formation. Rainwater and snowmelt infiltrate through cracks and fractures in these limestone layers, dissolving the carbonate minerals and thereby increasing the bicarbonate concentrations in the springs originating from these rocks. Given the similarity in rock types and climatic conditions—particularly the amount of rainfall in the river basin's catchment area—there is little variation in bicarbonate concentrations among the springs that feed into the Komel River.

Table 2. The physical and chemical parameters of the studied water samples

Para.	*Springs*			*Komel R.*				*springs*		*Komel R.*			Av.
	1	2	3	4	5	6	7	8	9	10	11	12	
pH	8.05	8.06	7.8	8.04	7.6	7.87	7.7	7.5	7.72	7.93	7.8	7.5	7.8
EC	585.7	457.1	685.7	614.2	642.8	628.5	600	528.5	642.8	600	514.2	514.2	584.5
TDS	415	351	466	463	472	427	405	385	435	441	345	352	413.1
TH	592	532	600	540	600	620	604	588	600	584	580	500	578.3
Ca^{2+}	49.7	36.9	49.7	40.1	46.5	51.4	44.9	44.9	44.9	43.3	51.4	35.7	45.0
Mg^{2+}	25.5	24	26	24	26.4	26.8	26.8	26	26.6	26.0	24.6	23.3	25.5
Na^{+}	12.8	2.3	17.8	12.7	12	12.5	12	2.1	13.9	11.6	8.5	7.6	10.5
K^{+}	1.8	0.9	2.4	1.8	3.5	1.9	2.2	0.9	1.2	2.2	1.0	2	1.8
HCO_3^-	200	188	212	200	212	216	192	196	216	204	205	184	202.1
SO_4^{2-}	60	10.1	68	51	53.5	52	67	38.3	49.5	42.0	45.5	42.1	48.3
Cl^-	33.3	25.8	37.4	31.5	31.6	28.8	27.8	22.4	38.1	34.1	32.1	30.4	31.1
NO_3^-	1.3	8.5	3	2.4	1.2	2.3	3.5	0.5	7	0.5	2.5	6	3.2

The second common anion in the springs and Komel River is sulphate, as indicated in Table (2), it ranges from 10.1 to 68 with an average 48.3mg/ l. The variation in sulfate concentrations is due to the nature of the exposed rocks in the region and the effect of erosion and chemical weathering factors on soil and weathered rock fragments. Gercus Formation has spread widely in the area and consists of thin layers of gypsum **(Ghafur *et al.*, 2019)**, in addition to the contribution of some outcrops of Fat'ha Formation in some areas of the foothills near the valleys. These outcrops help supply water with sulfates through runoff during rainfall or infiltrate to a soil horizons and rock beds near the surface. In contrast to the other springs, the Al-Saria and Zawita spring locations have comparatively high sulfate concentrations, as seen in Fig. (2). This mismatch was caused by a rise in sulfates in the Komel River in the Bedole region, which ranges from 51 to 67mg/ l, while sulfate levels in river water following the Khans region are significantly lower since spring water from the Kokhi and Belkafe districts has a low sulfate concentration.

Calcium and magnesium are the most common cations in the waters of the Komel River basin. There concentrations ranged from 35.7 to 51. 4 with an average of 45mg/ l and from 23.3 to 26.8 with an average of 25.5mg/ l, respectively. Depending on the effects of the carbonate solubility process, where the calcite mineral that is the primary mineral of the Shiranish, Kolosh, and Pila Spi rocks, calcium concentrations vary somewhat between the waters of the springs and the river (Fig. 2). Fig. (3) demonstrates that calcium has a stronger correlation to bicarbonate (r^2= 0.51) than to sulfates (r^2= 0.34), indicating that carbonate minerals have a greater impact on supplying calcium to water than gypsum because they are widely distributed in most rock sections in the river basin region **(Al-Jiburi & Al-Basrawi, 2012)**.

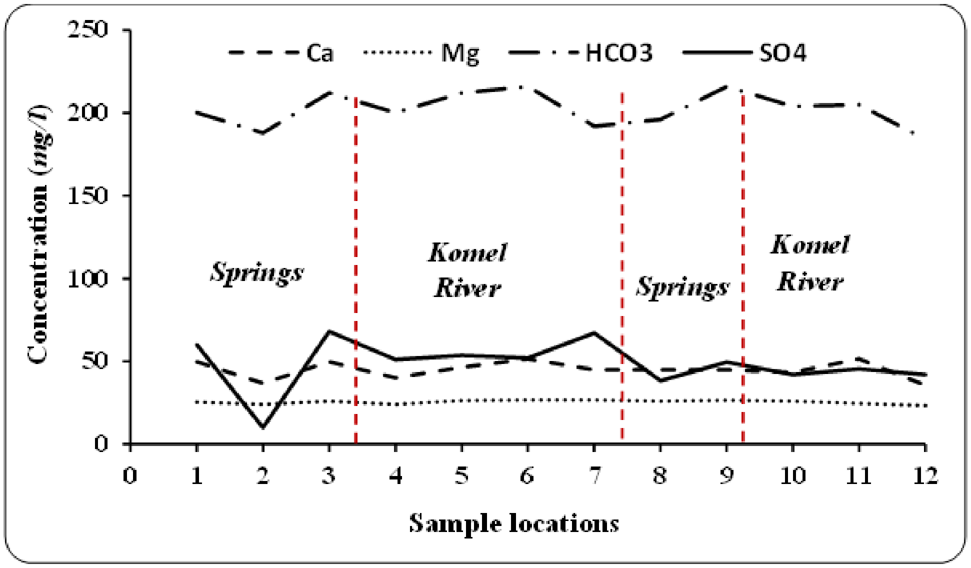

Fig. 2. The variations of Ca^{2+}, Mg^{2+}, HCO_3^- and SO_4^{2-} along Komel River (sample no.: 4, 5, 6, 7, 10, 11 and 12) and the tributaries of the springs (sample no.: 1, 2, 3, 8 and 9).

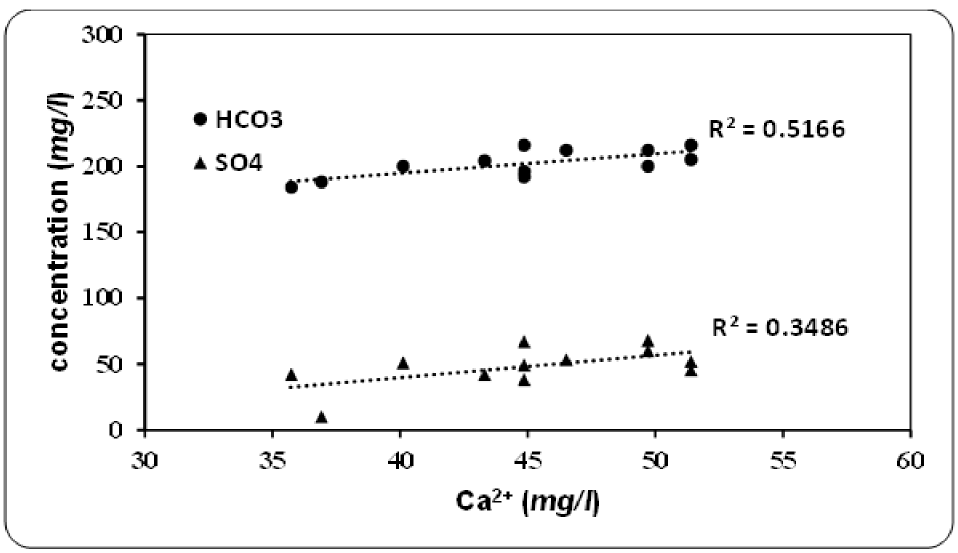

Fig. 3. Calcium correlated with bicarbonate in carbonate rocks more than sulfates in gypsum rocks.

The main source of magnesium is a dolomite rock, specifically from the Pila Spi Formation rocks, which are abundant in the area in the form of heights and mountain series. This may explain why there is no difference in magnesium concentrations between springs and river water **(Asaad & Balaky, 2021)**.

The concentrations of chloride and sodium ions in the solution range from 22.4 to 37.4 with an average of 31.1mg/ l, and from 2.1 to 17.8 with an average 10.5mg/ l, respectively. Figs. (4, 5) illustrate a strong relationship between sodium and chloride ions, with a correlation coefficient of $r^2 = 0.91$, indicating that these ions are present in the same mineral phase as halite. Halite, known for its high solubility, can be found as concretions or lenses within gypsum layers. As a result, sodium and chloride ions are released at the same rates from halite. The presence of secondary halite redeposited in small pits and surface fractures under dry conditions may be contributing to these ion concentrations. Variations in sodium and chloride concentrations between spring waters are attributed to the amount of halite present in the gypsum layers exposed in the area, as depicted in Fig. (5). In contrast, the concentrations in river water are nearly uniform, reflecting the combined effect of the streams feeding into the river.

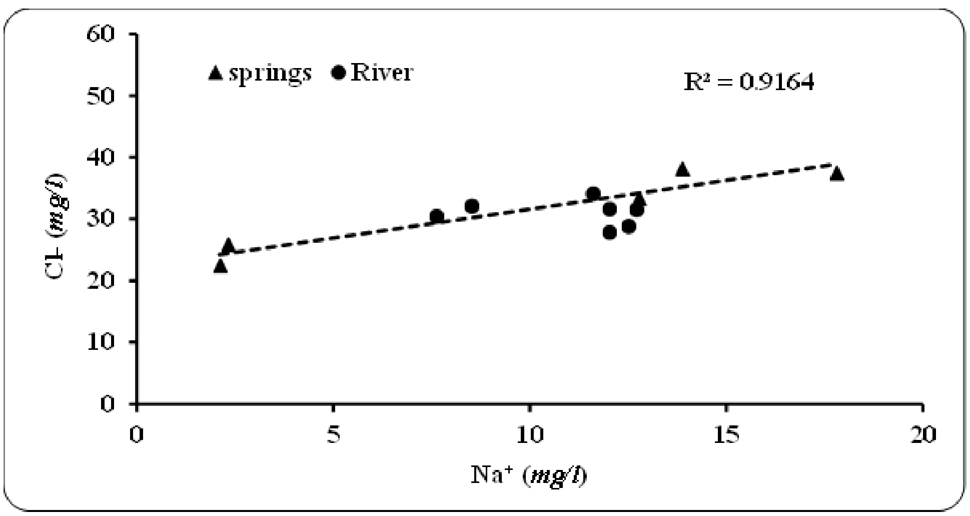

Fig. 4. The relationship between Na^+ and Cl^- in springs and river water.

Potassium is typically found in adsorbed form in clay minerals or within the unit cell of a clay mineral like illite. Its content in spring water and river water is quite low and ranges from 0.9 to 2.2 with an average of 1.8mg/ l, because the amount released from the clay minerals to the water is typically very small (Fig. 5).

High nitrate concentrations are often associated with agricultural activity because of the impact of biological activity through the waste of the organisms that are discharged to the water and organic and artificial fertilizers, which provide nitrates to the soil, in addition to bacteria's ability to stabilize atmospheric nitrogen oxides **(Dikeogu *et al.* 2018)**. In general, nitrate concentrations are subject to the influence of the decomposition of chemical and organic fertilizers prepared for the soil and the biological activity of nitrogen-fixing bacteria and plants located in the upper part of the soil horizon **(Deming, 2002)**. Nitrate concentrations in the studied water samples ranged from 0.5 to 8.5 with an average of 3.2mg/ l, which indicated a decline in agricultural activities that includes fertilization and animal husbandry. Fig. (5) shows a relative increase in nitrate concentrations in some springs (2 and 9), probably as a result of the adjacent agricultural activity in the areas next to the springs' streams.

The relatively low ion contents generally reflected the physical characteristics of water.

Table (2) shows a decrease in the total dissolved solids (TDS), which ranges from 345 to 472mg/ l, with an average of 413.1mg/ l. This reduction in TDS is also reflected in a decrease in electrical conductivity (EC), which ranges from 457.1 to 685.7µS/ cm, with an average of 584.5µS/ cm. Additionally, the total hardness, caused by ions of calcium, magnesium, bicarbonate, and sulfate, ranges from 500 to 620mg/ l, with an average of 578.3mg/ l.

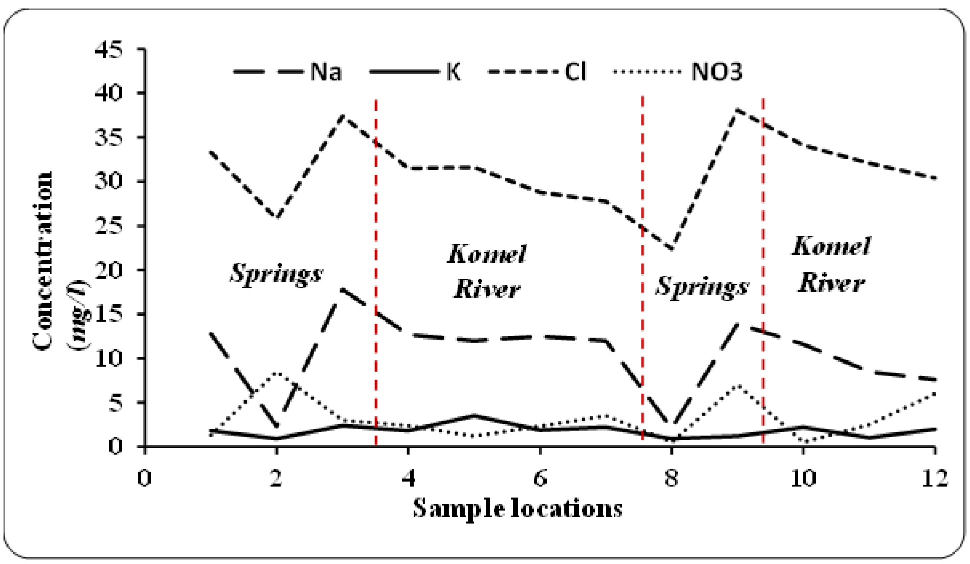

Fig. 5. The variations of Na^+, K^+, Cl^- and NO_3^- along Komel River (sample no.: 4, 5, 6, 7, 10, 11 and 12) and the tributaries of the springs (sample no.: 1, 2, 3, 8 and 9).

The pH levels ranged from 7.5 to 8.06, with an average of 7.8, which are acceptable for domestic use and fall within the natural range. However, there is a slight tendency toward alkalinity due to the effect of rainwater on dissolving exposed carbonate rocks. Rainwater, which contains low concentrations of carbonic acid formed from atmospheric carbon dioxide, penetrates through fractures and joints in the outcrops and dissolves carbonate rocks. These physical measurements indicate that the infiltration of precipitation into subsurface water has a minimal impact on the dissolving process.

Water classification

WQI for water samples fall into the category "good" according to **Gupta and Misra (2016)** divisions that range from 26 to 50. Thus, the spring water and the Komel River are suitable for drinking and domestic uses (Table 3).

Table 3. Water quality index (WQI) for the Komel River

Sample No.	WQI	Class	Sample No.	WQI	Class
1 (*Spr.*)	45.4	Good	**7** (*Riv.*)	39.3	Good
2 (*Spr.*)	42.1	Good	**8** (*Spr.*)	30.5	Good
3 (*Spr.*)	43.5	Good	**9** (*Spr.*)	40.6	Good
4 (*Riv.*)	50.8	Good	**10** (*Riv.*)	47.0	Good
5 (*Riv.*)	35.4	Good	**11** (*Riv.*)	42.7	Good
6 (*Riv.*)	46.1	Good	**12** (*Riv.*)	30.3	Good

Table (4) displays the concentrations of the cations and anions of the studied water samples in *meq/l*. These values were utilized to calculate the water balance between the cation and anion group. If the difference between the sum of the concentrations of both groups is less than 10, this reflects the accuracy of chemical analyses **(Baird *et al*., 2017)**. It appears that all samples fall within a range of less than 10%. The meq/l values were also used to calculate irrigation water classification parameters (Table 5).

Table 4. The chemical compositions in (*meq/l*) of the studied water samples

	springs			***Komel R***				***springs***		***Komel R***		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	12
Ca^{2+}	2.48	1.84	2.48	2.00	2.32	2.56	2.24	2.24	2.24	2.16	2.56	1.78
Mg^{2+}	2.10	1.97	2.14	1.97	2.17	2.20	2.20	2.14	2.19	2.14	2.02	1.92
Na^{+}	0.56	0.10	0.77	0.55	0.52	0.54	0.52	0.09	0.60	0.50	0.37	0.33
K^{+}	0.05	0.02	0.06	0.05	0.09	0.05	0.06	0.02	0.03	0.06	0.03	0.05
Total	**5.18**	**3.94**	**5.45**	**4.57**	**5.10**	**5.36**	**5.02**	**4.49**	**5.06**	**4.86**	**4.98**	**4.08**
HCO_3^{-}	3.28	3.08	3.47	3.28	3.47	3.54	3.15	3.21	3.54	3.34	3.36	3.02
SO_4^{2-}	1.25	0.21	1.42	1.06	1.11	1.08	1.39	0.80	1.03	0.87	0.95	0.88
Cl^{-}	0.94	0.7	1.0	0.89	0.8	0.8	0.7	0.63	1.0	0.96	0.9	0.8

		3	5		9	1	8		7		1	6
NO_3^-	0.02	0.14	0.05	0.04	0.02	0.04	0.06	0.01	0.11	0.01	0.04	0.10
	5.49	**4.16**	**5.99**	**5.27**	**5.50**	**5.47**	**5.38**	**4.65**	**5.76**	**5.19**	**5.25**	**4.85**
Total ionic balance	**2.88**	**2.70**	**4.72**	**7.05**	**3.74**	**1.03**	**3.46**	**1.71**	**6.42**	**3.27**	**2.64**	**8.60**

The waters were classified as fresh water since their TDS contents were less than 1000mg/ l **(Dewiest & Davis, 1966)**. Additionally, the water was classified as Type A due to EC < 750, (Tyler's classification in **Leizou *et al*., 2017**) which represents water with a low level of damage to crops. Based on the previous two parameters, the waters were classified as medium salinity (*C2*) by the American Salinity Laboratory **(Abbawi & Hassan, 1990)**.

Table (5) displays the water classification parameters for irrigation. The SAR values indicate that the waters are low sodic and fall into class S1, making them suitable for the irrigation of most crops and soil types, according to the classification of the American Salinity Laboratory. This is consistent with **Richard**'s **(1954)** classification, as referenced in **Abbawi and Hassan (1990)**, which categorizes the waters as "good" for irrigation, falling within the field of type (C2-S1).

Table 5. The classification parameters for irrigation of Komel River

Para-meters	***springs***			***Komel R***				***springs***		***Komel R***		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
SAR	0.37	0.07	0.51	0.39	0.35	0.35	0.35	0.06	0.41	0.34	0.24	0.24
SSP	10.74	2.54	14.19	12.07	10.22	10.14	10.39	2.03	11.94	10.38	7.42	8.10
RSBC	-1.30	-0.73	-1.14	-0.70	-1.02	-1.23	-1.30	-1.17	-0.89	-0.96	-1.23	-0.68
PI	35.38	44.86	34.71	40.12	37.29	35.52	35.83	40.12	37.51	38.18	37.05	43.20
MAR	45.82	51.73	46.30	49.66	48.34	46.22	49.59	48.83	49.40	49.74	44.09	51.82
KR	0.12	0.03	0.17	0.14	0.12	0.11	0.12	0.02	0.14	0.12	0.08	0.09

In general, the waters are deemed suitable for irrigation based on several parameters. The sodium percentage (SSP) values are less than 75%, and the magnesium adsorption ratio (MAR) is below 50%. These values suggest that increased sodium or magnesium would not significantly impact salinity levels, which can negatively affect crops and reduce soil ventilation and permeability. Additionally, the residual sodium carbonate (RSBC) values are below 1.25, indicating minimal calcium and magnesium bicarbonate sedimentation, and the absence of rising sodium concentrations that could harm the soil **(Joshi *et al.*, 2009)**. The permeability index (PI), which evaluates soil permeability with prolonged irrigation, classifies the waters as suitable for irrigation under category (Class II). Similarly, the Kelly's ratio (KR), which measures the ratio of sodium ions to calcium and magnesium ions, shows values below 1.0, further confirming the water's suitability for irrigation.

CONCLUSION

The spring water that feeds the streams flowing into the Komel River is considered suitable for drinking and domestic uses, based on water quality factor values that indicate that the water is of a good quality. Water evaluation parameters for agricultural purposes, such as *SAR, SSP, RSBC, MAR, PI* and *KR*, also indicate that the water is generally suitable for irrigation. In addition, the quality of the water does not change along the path of the river from the springs to its confluence with the Al-Khazer River.

The results of the study also support the idea of developing water harvesting projects in the secondary valleys of the Komel River basin, especially in mountainous areas. Due to the favorable topographic slope of the region, river water in the plains areas also supports the development of irrigation projects between the Komel River and the Al-Khazer River.

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REFERENCES

Abbawi, S. A. and Hassan, M. S. (1990). The Practice Engineering for Environment. Water Analysis. Dar Al-Hekma for Publishing, University of Mosul. Engineering for Environment. 296P.

Al-Hamdani, J.A.J.; Awadh, S.M. and Ibrahim, O.S. (2016). Geochemical partitioning of heavy metals in the urban soil, Kirkuk, Iraq. The Iraqi Geological Journal, 39-49 (1), 1-24.

Al-Jiburi, H. K. and Al-Basrawi, N. H. (2012). Hydrogeology of the Low Folded Zone. Iraqi Bull. Geol. Min., Special Issue, No.5, 2012: Geology of the Low Folded Zone, p 133− 157.

Al-Youzbakey, K.T. and Sulaima, A. M., (2021). Assessment of Water Quality along Greater Zab River within Iraqi Lands. Italian Journal of Engineering Geology and Environment, 1, 5-17.

Aqrawi, O.S. and Al-Mallah, A. Y. (2021). Hydrogeochemical Assessment of Selected Springs Water in Aqra Area, Duhok Governorate, Northern Iraq. Iraqi Geological Journal. 54 (2E), 134-149.

Asaad, I. Sh. And Balaky, S. M. (2021). Geotourism potential of Akre area, Duhok Governorate, Iraqi Kurdistan Region. Bulletin of the Geological Society of Malaysia, Vol. 71, 99 – 112.

Awadh, S.M. and Ahmed, R.M. (2013). Hydrochemistry and pollution probability of selected sites along the Euphrates River, Western Iraq. Arabian Journal of geosciences, 6(7), 2501-2518.

Awadh, S.M. and Al-Ghani, S.A. (2014). Assessment of sulfurous springs in the west of Iraq for balneotherapy, drinking, irrigation and aquaculture purposes. Environmental geochemistry and health, 36(3), 359-373.

Awadh, S.M.; Al-Mimar, H. and Yaseen, Z.M. (2021). Groundwater availability and water demand sustainability over the upper mega aquifers of Arabian Peninsula and west region of Iraq. Environment, Development and Sustainability, 23(1), 1-21.

Aziz, Y. W.; Saeed, M.A.H. and Ahmed, S.S. (2020). Estimation of Annual Runoff and Peak Flow at Nazanin Catchment in Erbil, Kurdistan Region Using Different Approaches. Iraqi Geological Journal, 53 (2E), 96-106.

Baird, R. B.; Eaton, A.D. and Rice, E. W. (2017). APHA, Standard Methods for the Examination of Water and Wastewater. 23rd.American Public Health Association. American Water Works Association and Water Environment Federation, 1504P.

Basavaraja, S.; Hiremath, S.M.; Murthy, K.N.S.; Chandrashekarappa, K. N.; Anil N. P. and Puttiah, E. T. (2011). Analysis of water quality using physico-chemical parameters Hosahalli Tank in Shimoga District, Karnataka, India, Global J. Sci. Frontier Res., 11, pp.31 – 34.

Beg, A.A.F.; Awadh, S.M.; Thamer, M.B. and Al-Sulttani, A.H. (2021). Assessment of Groundwater Quality for Drinking Purposes Using Water Quality Index, and Identifying the Affecting Mechanism in Rashdiya, Central Iraq. Iraqi Geological Journal, 54 (1F), 20-32.

Boschetti, T.; Awadh, S.M. and Salvioli-Mariani, E. (2018). The Origin and MgCl 2–NaCl Variations in an Athalassic Sag Pond: Insights from Chemical and Isotopic Data. Aquatic Geochemistry, 24(2), 137-162.

Davis, S.N. and Dewiest, R.J.M. (1966). Hydrogeology. John Wiley & Sons, New York, 108P.

Deming, D. (2000). Introduction to Hydrogeology. McGraw-Hill Co. 468P.

Dikeogu, T.C.; Okeke, O.C.; Ogbekhiulu, L.O. and Ogbenna, P. C. (2018). Major ion chemistry and hydrochemical processes of Ngeneagu spring water at Akpugoeze

Oji River, Enugu, and southeastern Nigeria, International Journal of Advanced Academic Research Sciences, Technology & Engineering, 4(2), 13pp.

Ghafur, A. A.; Sissakian, V. K.; Abdulhaq, H. A. and Omar, H. O. (2019). Aqra Anticline: A growing structure in the Iraqi Kurdistan Region. ARO-The Scientific Journal of Koya University, 7(2), 27-33.

Gupta, R. and Misra, A. K. (2016). Groundwater quality analysis of quaternary aquifers in Jhajjar District, Haryana, India: Focus on groundwater fluoride and health implications. Alexandria Engineering journal (Available online, 2016).

Hamrawi, M. Sh. and Ibrahim I. A. (2021). Specifying the Vegetation Cover Changes in Komel River River Using Remote Sensing Techniques. Iraqi National Journal of Earth Sciences, 21 (2), 17-26.

Jabir, A. A.S. (2020). Geomorphological analysis of the morphometric properties of Harba basin, Al-Adab Journal, Vol. 1, (135), 447-478.

Jassas, H. and Merkel, B. (2014). Estimating Groundwater Recharge in the Semiarid Al-Khazir - Gomal Basin, North Iraq. Water 6, 2467-2481; doi:10.3390/w6082467.

Joshi, D.M.; Kumar, A. and Agrawal, N. (2009). Assessment of the irrigation water quality of River Ganga in Haridwar District India. J. Chem., 2(2): 285-292.

Kachroud M.; Trolard, F.; Kefi, M.; Jebari, S. and Bourrié, G. (2019). Water Quality Indices: Challenges and Application Limits in the Literature. Water, 11, 361, 1-26. doi:10.3390/w11020361, www.mdpi.com/journal/water.

Leizou, K.E.; Nduka, J. O. and Veria, A.W. (2017). Evaluation of Water Quality Index of the Brass River, Bayelsa State, South Nigeria. Jou. Res. Granthaalayah, Vol. 5, No. 8, pp 277-287.

Medler, C. J. and Eldridge, W. G. (2021). Spring types and contributing aquifers from water-chemistry and multivariate statistical analyses for seeps and springs in Theodore Roosevelt National Park, North Dakota, 2018 (No. 2020-5121). US Geological Survey.

Meuli, C. and Wehrle, K. (2001). Spring Catchment–Series of Manuals on Drinking Water Supply. Swiss Center for Development Cooperation in Technology and Management–SKAT, Suiza. Piper, A. M., 1944. A graphic procedure in the geochemical interpretation of water-analyses. Eos, Transactions American Geophysical Union, 25(6), 914-928.

Obiefuna, G.I. and Sheriffm A. (2011). Assessment of Shallow Ground Water Quality of Pindiga Gombe Area, Yola Area, NE, Nigeria for Irrigation and Domestic Purposes. Res. J. Environ. Earth Sci., 3, 131–141.

Sissakian, V.K. and Al-Jiburi, B. S. M. (2014). Stratigraphy of the High Folded Zone. Iraqi Bull. Geol. Min., Special Issue, No.6, 73-161.

Sissakian, V.K.; Kadhim, T.H. and Jab'bar, M.F.A. (2014). Geomorphology of the high folded zone. Iraqi Bulletin of Geology and Mining, (6), 7-51.

WHO, (2006). World Health Organization, Guidelines for Drinking Water Quality [electronic resource]: Incorporating First Addendum, Recommendations., 1.