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RESEARCH PAPER

Spring Water Quality Assessment Using Water Quality Index in Shawre Valley- Sulaymaniyah-Iraqi Kurdistan Region

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A B S T R A C T:

The current study was conducted to assess the suitability of springs for drinking purposes in Shawre Valley in Sulaymaiyah Governorate, Kurdistan region of Iraq, using the Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI). Water samples were collected from four springs (Daraban, Mam Xalan, Dolli Shawre, and Sarukani) and analyzed for seventeen physicochemical parameters including Turbidity, Hydrogen Ion Concentration (pH), Electrical Conductivity (EC), Total Dissolved solids (TDS), Total hardness, Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Total Alkalinity, Sodium (Na^{+}), Potassium (K^{+}), Chloride (Cl^{-}), Sulfate (SO_4^{2-}), Nitrate (NO_3^{-}), Nitrite (NO_2^{-}), Phosphate (PO_4^{3-}), Dissolved oxygen (DO), and Biochemical oxygen demand (BOD_5) from October 2021 to February 2022. The results of physicochemical parameters indicated that most of the spring's water samples lie within the permissible limit as compared by WHO for drinking purposes, except for Turbidity, EC, TDS, Total hardness, Mg^{2+}, DO, and BOD_5, which exceed the standard values at Daraban, Mam Xalan, and Dolli Shawre springs and are considered unfit for drinking consumption. The results showed that the calculated CCME WOI values ranged from 74.00 to 88.45. Generally, the overall water quality index showed that Mam Xalan spring of 64.00 falls under the "Marginal" category, while Daraban and Dolli Shawre of 65.00 and 78.45 respectively fall under "Fair" quality. Furthermore, Sarukani spring of 88.079 falls under "Good" quality. On the basis of WQI results, most of the spring water samples fall under the Fair and Marginal categories, indicating that they require proper treatment for drinking purposes.

KEY WORDS: CCME Water Quality Index, Drinking water, Physicochemical properties, Shawre Valley, Spring water.
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1. INTRODUCTION :

Water is a vital natural resource and the most important element on the planet for human life (Issa, 2017). As a result of the increased demand for good water quality, there is a worldwide increased interest in providing safe water for various uses such as drinking, irrigation, industrial uses, and economic activities (Al Saleh, 2021). According to the WHO report, more than 80% of human health issues are related to inadequate sanitation and poor drinking water quality (WHO, 2004). Even though water covers 80% of the earth's surface, fresh water supply has become a limiting factor (Shigut et al., 2017). Only 1% of the world's water resources are fit for human consumption (Hashmi et al., 2009).

Freshwater resources are steadily declining as the world's population grows. The exponential increase of urbanization and climate change, particularly in developing countries, continue to exert a detrimental effect on freshwater quality and quantity (Bruch, et al., 2011).

In the Iraqi Kurdistan region, the water sources for human activities include groundwater, rivers, dams, ponds, wells, and springs. Spring is not the main source for drinking, agricultural, and domestic purposes in the Iraqi Kurdistan Region. But that may be the main source in the study area. Springs are a plentiful source of fresh water for people all over the world. A spring is a water source created when a flowing body of groundwater makes contact with the side of a hill, the bottom of a valley, or another excavation at or below the nearby water table, where the

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subsurface material is saturated with water. Furthermore, springs develop when groundwater fills to the point of overflowing onto the land surface (Vilane and Dlimini, 2016).

The quantity and quality of such water sources vary based on their geographic area and environmental factors such as soil formation, lithology, porosity, the permeability of topsoil, hydrogeomorphology, surface slope, precipitation amount, the chemical makeup of the rock layers, and how long the water body has been trapped underground (Haque et al., 2020; Faniran et al., 2001). Spring water, on the other hand, is inexpensive and of high quality; however, when spring waters flow out and engage with the surface, it undergoes rapid contamination (Bui, et al., 2020). As stated by Daghara et al. (2019), spring ecosystems are under severe threat as a result of increased anthropogenic activity, which needs urgent attention and management plans.

Water quality indicates the suitability of water for human consumption, and the water quality of any specific area or source can be assessed using water parameters (physical, chemical, and biological parameters) (Bureau, 2012). Although most spring water is of high quality because it is filtered through soil horizons, its quality is determined by its chemical composition and physiochemical characteristics (Ameen, 2019). Thus, the Water Quality Index (WQI) can be used to assess water quality. The Canadian Council of Ministers of the Environment (CCME WQI) aids in the transformation of multiple parameters into a single dimensionless number that depicts the overall status of water quality at a specific location over time. The WQI has become one of the most popular and effective tools for assessing the health status of spring water quality (Espejo et al., 2012), by presenting information in an understandable and usable format for the public (Singh et al., 2021). The final data is displayed as values and transformation tables, making it simple for a layperson to comprehend by just looking at it. The village population of Shawre Valley in the Sulaimaniyah Governorate has relied heavily on spring water since time immemorial. To date, the quality of springs within the Shawre Valley area has not been directly studied. The main objectives of the current study are as follows:

1. Evaluation of the physicochemical parameters for some spring water in Shawre Valley Sulaymaniyah Governorate and comparing them with the WHO standards.
2. Classification the study of spring waters for drinking purpose using CCME WQI.

2. MATERIALS AND METHODS:

2.1. Study area

Sulaimaniyah Governorate, one of Iraqi Kurdistan's major cities, is located in the country's north and comprises a population of over a million people. The Governorate is situated at the crossroads of Longitude 45.44312° and Latitude 35.55719°, with an elevation of approximately 850 m above sea level (Mohammed et al., 2014). The weather in the Governorate is dry and warm in the summer, with a mean temperature of 31.5°C, and cold and wet in the winter, with a mean temperature of 7.6°C. Sulaimaniyah Governorate is divided into 15 districts: Sulaimaniyah, Darbandikhan, Sharazure, Saidsadiq, Penjwin, Halabja, Chamchamal, Kalar, Khanaqin, Kifri, Dukan, Qaradagh, Sharbazher (Mawat), Pishdar and Ranya (Figure 1b). Dolli Shawre, also known as Baradanga in general, is located in the Rania region of Sulaymaniyah at 36° 22' 41" North and 44° 44' 22" East. It is approximately 132 km far from Sulaimaniyah Governorate. The studied sites located in Bardanga (Dolli shawre) namely Draban, Mam Xalan, Sarukani, and Dolli Shawre (Figure. 1c)

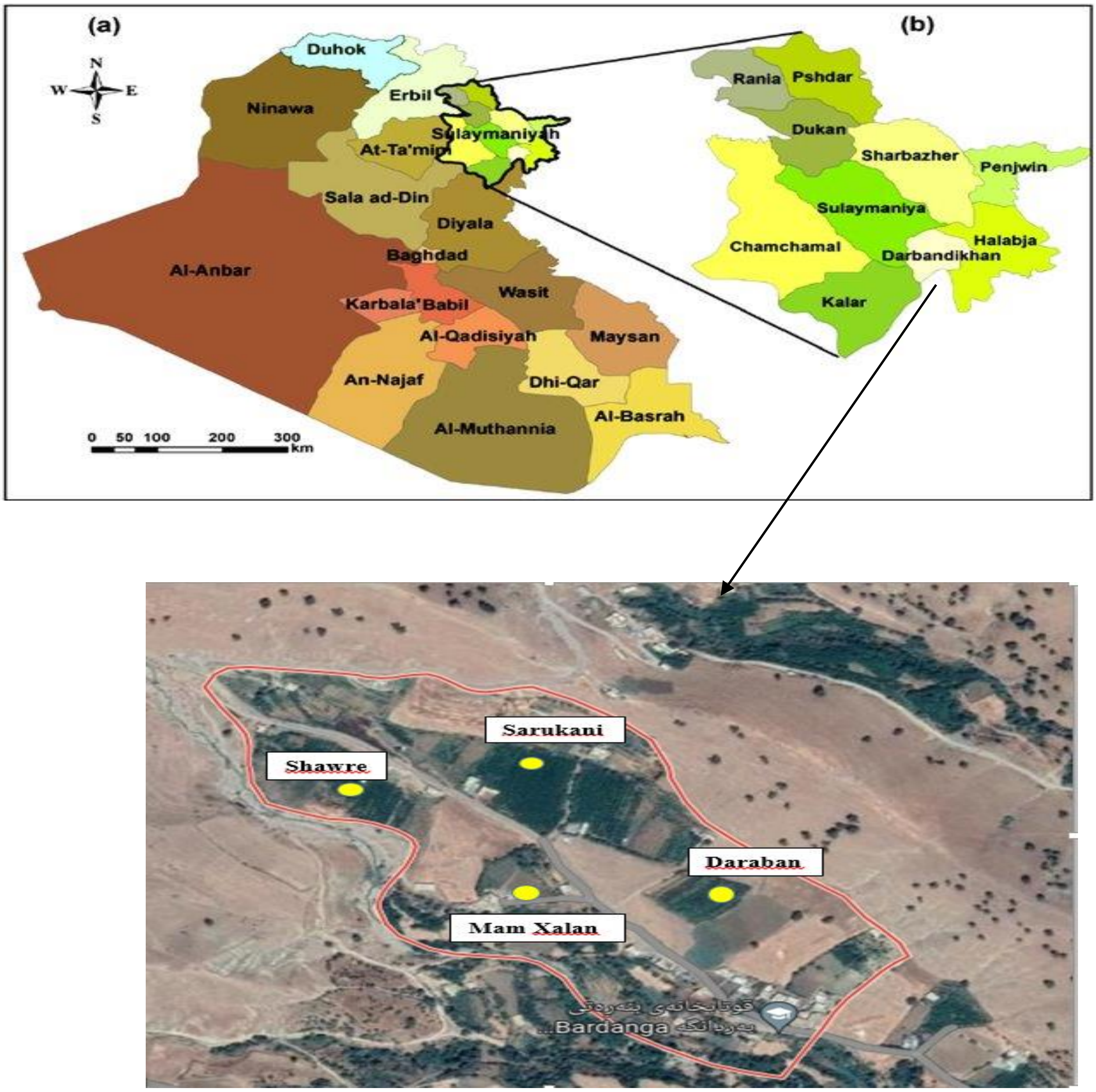

Figure 1 (a): Map of Iraq.
(b): Map of Sulaimaniyah Governorate.
(c): Shawre Valley district showing studying sites.

2.2. Sample collection

Water samples were collected from four spring sites within Shawre valley in Sulaimaniyah Governorate, Kurdistan region of Iraq (Figure 2), namely (Daraban, Mam Xalan, Srukani, and Dolli Shawre) at monthly intervals from October 2021 and extended to February 2022, excluding December; for their suitability for drinking purposes, 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. The samples were analyzed as per standard methods (APHA 1998) for Physicochemical parameters namely; Turbidity, pH (Hydrogen ion concentration), EC (Electrical conductivity), Total dissolved solids (TDS), Total hardness, Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Total Alkalinity, Sodium (Na^{+}), Potassium (K^{+}), Chloride (Cl^{-}), Sulfate (SO_4^{2-}) Nitrate (NO_3^{-}), Nitrite (NO_2^{-}), Phosphate (PO_4^{3-}) Dissolved Oxygen (DO), and Biochemical Oxygen Demand (BOD_5).

PH, EC and TDS were measured directly in the field by using (the PH-EC-TDS meter, Model Jenway-3540). Turbidity was measured by (Palin test Micro 950 – Turbidity meter), Total hardness, Calcium (Ca^{2+}), and Magnesium (Mg^{2+}) were measured by (EDTA titrimetric method), Sodium (Na^{+}) and Potassium (K^{+}) cations were determined by Flame Emission Photometer method, the analysis of the parameters for chloride

(Cl^-) and sulfate (SO_4^{2-}) according to Bartram and Balance (1996). The (Argentometric method) was used to determine Chloride (Cl^-), Nitrate (NO_3^-) was analyzed by colorimetric method using digital ultraviolet spectrophotometric screening method (JENWAY 6305 Spectrophotometer), Nitrite (NO_2^-) and Phosphate (PO_4^{3-}) were determined by spectrophotometer, Azide modification of the classical Winkler procedure (fixed directly in the field) was used to determine Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD_5) was done after five days incubation at 20°C according to (APHA, 1998).

Figure 2: Image of some springs utilized as drinking water sources at the sampling stations (A) Daraban, (B) Mam Xalan, (C) Sarukani, and (D) Dolli Shawre.

2.3. CCME-WQI calculation

The CCME WQI was created to be used as a tool for simplifying and defining water quality data. To calculate the CWQI, three measures (F_1= scope, F_2= frequency, and F_3= amplitude) were chosen as follows (CCME, 2001):

1- *F_1 (Scope)*

$$F1 = \left[\frac{Number\ of\ failed\ variables}{Total\ number\ of\ variables}\right] \times 100$$

2- *F_2 (Frequency)*

$$F2 = \left[\frac{Number\ of\ failed\ tests}{Total\ number\ of\ variables}\right] \times 100$$

3- *F_3 (Amplitude)*

$$F3 = \left[\frac{nse}{0.01\ nse + 0.01}\right]$$

$$nse = \left[\frac{\sum_{i=1}^{n} Excursion}{Number\ of\ tests}\right]$$

Whereas the test result may not exceed the objective:

$$Excursion\ i = \left[\frac{Failed\ test\ value\ i}{Objective\ j}\right] - 1$$

In cases where the test results may not fall below the objective:

$$Excursion\ i = \left[\frac{Objective\ j}{Failed\ test\ value\ i}\right] - 1$$

The CCMEWQI can be calculated using the following formula:

$$WQI = \frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}$$

The CWQI ranks water quality in five categories (Table 1):

Table 1- Shows the CWQI ranks water quality in 5 categories.

Rank	Poor	Marginal	Fair	Good	Excellent
CCME-WQI	0-44	45-64	65-79	80-94	95-100

3. RESULT AND DISCUSSION.

3.1. Physicochemical water quality assessment

A total of 16 water samples taken from four springs in Shawre Valley—Sulaiamaniya Governorate from October 2021 to February 2022 were tested for physicochemical properties. Turbidity, pH, EC, TDS, Total hardness, Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Total Alkalinty, Sodium (Na^{+}), Potassium (K^{+}), Chloride (Cl^{-}), Sulfate (SO_4^{2-}) Nitrate (NO_3^{-}), Nitrite (NO_2^{-}), Phosphate (PO_4^{3-}), Dissolved Oxygen (DO), and Biochemical Oxygen Demand (BOD_5), were among the water quality parameters studied. These parameters can influence the potability and appearance of spring water. All of the results are compared to the WHO drinking water guidelines' standard permissible limit. The physicochemical parameters analyzed in the current study are represented in the tables (2–5).

Turbidity is a measurement of the clarity or cloudiness of water. In this study area (Tables, 2-5), the results of turbidity throughout this survey ranged from 5 NTU in Sarukani spring to 44 NTU in Daraban spring. All the samples during the study period had turbidity values greater than the objective value of 5 NTU for drinking water (WHO, 2004), except for Sarukani Spring, which recorded a value close to the objective value for drinking water in November. The high turbidity values observed in this study indicate the absence of a water spring's filtration process, as well as that springs, are polluted with suspended materials and natural colloids like silt and clays (Damo and Icka, 2013). This is because to the location of the spring sites lies within a touristic area where ordinary people pay a visit for touristic purposes. Oftentimes, people dispose of their leftovers by throwing them into the sites which consequently leads to contamination. Furthermore, this might be a result of spring interaction with surface water, especially during spring runoff or heavy rains (Barakat et al., 2018).

The pH scale is useful for measuring the acidity or alkalinity of water. The World Health Organization WHO suggests a pH range of 6.5-8.5. The pH levels in the current investigation, ranging from 7.5 in Mam Xalan spring to 8.5 in Daraban spring (Table, 2), indicating that the water samples are alkaline. The pH value obtained is considered normal because, in general, the pH of water in the Iraqi Kurdistan region is distinguished by a shift towards the alkaline side of neutrality as a result of the area's geological formation, which is mainly composed of $CaCO_3$ (Toma et al., 2013; Al Jiburi and Al Basrawi, 2015; and Shekha, 2016). Overall, the findings show that all spring water samples fall within the acceptable range of WHO standards. This agrees with the finding that was recorded by (Abdulwahid, 2013).

Electrical conductivity (EC) is the capacity of an aqueous solution to carry an electric current. Electrical conductivity is a useful tool for determining the purity of water. The EC values for the investigated study period varied from 430 µS/cm in Sarukani spring in February to 1506 µs/cm in Mam Xalan spring in October. Accordingly, results showed that all the studied sites of spring waters have lower values than the WHO standards (1000 µS/cm), except for Mam Xalan spring (Table 3), which recorded higher values during the whole period of the study as (1506, 1313, 1410, and1445 µS/cm) respectively. Therefore, they are considered unfit for human consumption. The high conductivity of Mam Xalan spring water samples corresponded to high concentrations of dominant ions due to ion exchange and aquifer rock solubility (Virkutyte and Sillanpää, 2006). On the other hand, it depends on the climate, soil, geological origin, and the content of ionic salts (Wetzel, 1975).

Total Dissolved Solids (TDS) are inorganic substances that dissolve in water. The total dissolved solids (TDS) concentration in this study ranged from 84-752 mg/L, as shown in (Tables 2-5). So, according to TDS classification, all of the spring water samples belonged to the freshwater type (TDS 500 mg/L), the permissible limit set by (WHO, 2004), with the exception of freshwater spring Mam Xalan (Table 3), which recorded values higher than the other springs of 752, 724 mg/L in October and February, respectively. These higher TDS readings could be the result of the natural weathering of specific sedimentary rocks, or the presence of a large number of ions or minerals in them, as well as a higher salinity level. (Akram et al., 2020; Al Sudani, 2021). Thus, most of the spring results at the study sites were acceptable, and the concentration of TDS was not harmful.

Water hardness is a measurement of its capacity to form precipitates with soap and scales with water-soluble anions. Because hardness is expressed in terms of Ca^{+2} and Mg^{+2} ions, the amount of these ions in the water indicates its quality. Total hardness levels varied from 100-450 mg $CaCO_3$/L. According to WHO guidelines, all spring water samples were above the allowable limit of 200 mg $CaCO_3$/L (Tables, 2-3), especially in Daraban and Mam Xalan springs during the study period, while the water samples from the other springs remained within the allowable limits for drinking. Therefore, these results indicate the hard water character of the springs. The Valley's limestone, gypsum, and dolomite rocks are the main sources of Ca^{+2} and Mg^{+2} ions. The majority of springs run into hard or extremely hard water (Hameed et al., 2018; Bhat et al., 2022).

Calcium ($Ca^{2+)}$ and Magnesium (Mg^{2+}) ions are critical parameters for assessing water quality. Ca^{2+} and Mg^{+2} are directly related to hardness. All of the samples had calcium and magnesium levels ranging from 22 to 76 mg/L and 5.2 to 73 mg/L, respectively (Tables 2-5). These values were below the WHO calcium and magnesium limits of 100 mg/L and 30 mg/L, respectively (WHO, 2004), except for magnesium, which recorded greater values in Daraban and Mam Xalan springs during the whole study period. In general, calcium concentration is more than magnesium in the study area. This is because the Kurdistan region's geological formation is mainly composed of limestone (Chauhan and Singh, 2010). In addition, according to (Bui et al., 2020), these springs with abundant carbonate rocks in the catchment area, show higher magnesium concentrations. Magnesium in high concentrations causes water hardness and gastrointestinal irritation (Ibeneme et al., 2013).

Total alkalinity in water is caused by the presence of dissolved minerals like hydroxides, carbonates, and bicarbonates. It's defined as the ability to neutralize acids. The total alkalinity concentration varied between 130 mg $CaCO_3$/L as the minimum value in Dolli Shawre spring in February and 394 mg $CaCO_3$/L as the maximum value in Mam Xalan spring in November. According to WHO standards, the findings of most of the spring water during the study period exceeded the permissible limit of 200 mg $CaCO_3$/L, except for a few of them. High alkalinity values may be due to the prevailing land use type and recharge zones, as well as the presence of carbonate and bicarbonate released from rocks (Bhat et al., 2010) and the geological area (Batool et al., 2018).

Sodium (Na^+) in the groundwater is derived mainly from salt demineralization and silicate weathering, which is typically derived from the leaching of geological formations containing sodium chloride, as well as rock salt decomposition like sodium and aluminum silicates (Ziani et al., 2017; Belghiti, 2013), whereas potassium (K^+) in groundwater is primarily derived from feldspar, some micas, and clay minerals (Alikhan et al., 2020). In the current study, sodium and potassium levels ranged from 1.6 to 6.3 and 0.7 to 8.5 mg/L, respectively (Table, 2-5). The concentrations of all the spring's water samples were very low compared to the WHO limit of 200 mg/L and 10 mg/L, for both sodium and potassium respectively. Low Na^+ is most likely due to low NaCl, as well as low sodium and aluminum silicates in the study area's soils. On the other hand, low K^+ could be a result of these sites' low rock mineral composition or low geochemical mobility. As a result, there was no potassium or sodium contamination (Wirimvem et al., 2013), and the water was safe for drinking and other domestic purposes.

Chloride (Cl^-) is the most dominant anion in water, and it gives the water a salty taste. Chloride is abundant in nature in the salt forms of sodium (NaCl), calcium (CaCl), and potassium (KCl), and is an important water quality indicator. Furthermore, many natural and anthropogenic factors, such as geological sedimentation, agricultural use, and irrigation disposal, domestic effluent, add chloride elements to groundwater through leaching from rocks (Barakat et al., 2018). In the study area (Tables 2-5), the chloride value ranges from 10–21 mg/L. The lowest value (10 mg/L) was found in Mam Xalan spring in November, while the highest value (21 mg/L) was found in Mam Xalan spring in February. The concentration of chloride should not exceed 250 mg/L, according to WHO guidelines. As a result, all of the spring's water samples were found to be below the WHO (WHO, 2004) permissible limit, indicating that the water was fresh and safe to drink.

Sulfate (SO_4^{2-}) is a critical chemical factor for water quality that affects the odor and taste of drinking water. If high concentrations are consumed in drinking water, there may be objectionable tastes or unwanted laxative effects, but there is no significant risk to public health (Bouslah, et al., 2017). Sulfate is primarily derived in the aquifer system through the dissolution of two major types of sulfate-containing rocks, such as gypsum and pyrite which underlies the springs (Ziani et al., 2017). Sulfate concentrations in spring water samples ranged from 60 in Dolli Shawre in October to 173 mg/L in Mam Xalan in November (Tables 2–5); indicating that they were below the WHO limit of 250 mg/L for sulfate and thus suitable for drinking.

Nitrate (NO_3^-) and nitrite (NO_2^-) are naturally occurring ions in the nitrogen cycle. Nitrate ions in water are toxic. Because it causes methemoglobinemia in infants under the age of six months, also known as blue baby syndrome. In the current study, the nitrate NO_3^- contents of spring water samples were found to be ranged from 3.5 mg/L in Daraban and Mam Xalan springs in November to 68 mg/L in Daraban spring in October, while nitrite NO_2^- contents ranged from 0.2 mg/L in Sarukani spring in November to 0.43 mg/L in Dolli Shawre in November. With the exception of the Daraban spring (Table 2), which recorded a higher nitrate value of 68 mg/L in October and was declared unfit for drinking, the NO_3^- levels in all spring water samples were well below the WHO-recommended limit (50 mg/L) (WHO, 2004). Natural NO_3^- concentrations in groundwater are usually low, but they raise as a consequence of anthropogenic activities such as the discharge of domestic and septic tank effluent and agricultural activities (Ameen, 2019). Furthermore, water containing more than 3 mg/L of nitrite NO_2^- should not be used for baby feeding (Kumar and Puri, 2012). The water from all springs in the current study was safe for baby feeding because the NO_2 levels were all well below 3 mg/L (Chauhan et al., 2020).

Phosphate (PO_4^{3-}) is widely regarded as an essential nutrient for the proper functioning of the aquatic ecosystem. Phosphate sources can be artificial or anthropogenic, depending on the area's human activities. Phosphate concentrations in spring water could be high because of agricultural runoff or washing from nearby phosphate-fertilized farmland (Gurung et al., 2019). The current study (Tables 2–5) found that phosphate (PO_4^{3-}) levels ranged from 1.0 mg/L in Mam Xalan sping in October and February to 2.8 mg/L in Daraban spring in November. The water samples from all of the springs were within the recommended limits of 4 mg/L (WHO, 2004), indicating that there was no health risk associated with phosphate in the study area's springs.

Dissolved oxygen (DO) indicates metabolic balance and reflects the water quality status of physical and biological processes in water. DO levels are used to assess the health of a body of water. Saturated oxygen water has a pleasant taste (Krishan et al., 2016). The DO ranges from 4.00 to 12.00 mg/L. Daraban spring in November had the highest value of 12.00 mg/L, while Sarukani spring in September had the lowest value of 4.00 mg/L. According to the standard limit of DO in drinking water, which is 5 mg/L, the DO values are unexpectedly high and unsatisfactory for drinking use. Organic matter decomposition, industrial waste, dissolved gases, and agricultural runoff all contribute to a lower DO level. DO concentrations below 5.0 mg/L have a negative impact on aquatic life (Kannel et al., 2007).

Biochemical Oxygen Demand (BOD_5) is a critical parameter for determining water quality. BOD_5 is a measure of how much oxygen bacteria consume during the aerobic decomposition of organic matter. Organic matter degradation in water consumes available DO, resulting in rapid depletion of available DO and high BOD_5 (Mustapha et al., 2013). The BOD_5 levels in the current study ranged between 2.00 and 9.8 mg/L. Sarukani spring in December had a minimum concentration of 2.00 mg/L and Daraban spring in November had a maximum concentration of 9.8 mg/L. As a result, the majority of the spring's water samples exceeded the allowable limit of 5 mg/L established by WHO Standards (Tables 2-

5). Thus, these studied sites are considered polluted water sources and unsafe for drinking purposes. High BOD_5 levels may indicate high organic matter accumulation and elevated microbial activity in these springs (Vigiak et al., 2019).

Table 2: Physicochemical analyzes in Daraban spring during study period

Parameter	October	November	January	February	Mean	WHO (2004)
Turbidity (NTU)	**44**	**8**	**26**	**41**	**29.75**	**5**
pH	8.5	7.7	8.4	8.1	8.175	**6.5-8.8**
EC (μS/cm)	932	744	832	693	800.25	**1000**
TDS (mg/L)	467	476	472	402	454.25	**500**
Hardness ($mgCaCO_3/L$)	**233**	**276**	**251**	**231**	**247.75**	**200**
Ca^{2+} (mg/L)	42	38.7	40.4	40	40.275	**100**
Mg^{2+} (mg/L)	**30.7**	**43**	**37**	**31**	**35.425**	**30**
Alkalinity ($mgCaCO_3/L$)	194	**343**	**272**	196	**251.25**	**200**
Na^+ (mg/L)	2.5	3.5	3	2.5	2.875	**200**
K^+ (mg/L)	1.2	1.5	1.4	1.1	1.3	**10**
Cl^- (mg/L)	14	11	13	11	12.25	**250**
SO_4^{2-} (mg/L)	71	110	91	66	84.5	**250**
NO_3^- (mg/L)	**68**	3.5	35.8	4.5	27.95	**50**
NO_2^- (mg/L)	0.41	0.34	0.38	0.4	0.3825	**3**
PO_4^{3-} (mg/L)	3	2.8	3	2	2.7	**4**
DO (mg/L)	**10**	**12**	**11.2**	**11**	**11.05**	**5**
BOD_5 (mg/L)	**8.4**	**9.8**	**9.1**	**9.1**	**9.1**	**5**

Bold values mean more than the maximum permissible value.

Table 3: Physicochemical analyzes in Mam Xalan spring during study period

Parameter	October	November	January	February	Mean	WHO (2004)
Turbidity (NTU)	**29**	**6**	**17**	**26**	**19.5**	**5**
pH	8.2	7.5	8	8	7.925	**6.5-8.8**
EC (μS/cm)	**1506**	**1313**	**1410**	**1445**	**1418.5**	**1000**
TDS (mg/L)	**752**	84	420	**724**	495	**500**
Hardness ($mgCaCO_3/L$)	**422**	**450**	**436**	**398**	**426.5**	**200**
Ca^{2+} (mg/L)	73	60	66.2	76	68.8	**100**
Mg^{2+} (mg/L)	**57.6**	**73**	**65.3**	**52**	**61.975**	**30**
Alkalinity ($mgCaCO_3/L$)	**203**	**394**	**290**	**201**	**272**	**200**
Na^+ (mg/L)	3.5	4.7	4.2	3.3	3.925	**200**
K^+ (mg/L)	1.2	2	1.5	1.2	1.475	**10**
Cl^- (mg/L)	19	10	15	21	16.25	**250**
SO_4^{2-} (mg/L)	119	173	146	125	140.75	**250**
NO_3^- (mg/L)	5	3.5	4.4	4.7	4.4	**50**
NO_2^- (mg/L)	0.24	0.4	0.32	0.21	0.2925	**3**
PO_4^{3-} (mg/L)	1	1.4	1.3	1	1.175	**4**
DO (mg/L)	**5.6**	**5.1**	**5.3**	**5.1**	**5.275**	**5**
BOD_5 (mg/L)	4	4	4.2	4	4.05	**5**

Bold values mean more than the maximum permissible value.

Table 4: Physicochemical analyzes in Sarukani spring during study period

Parameter	October	November	January	February	Mean	WHO (2004)
Turbidity (NTU)	**27**	5	**16**	**28**	**19**	**5**
pH	7.8	7.6	7.7	7.7	7.7	**6.5-8.8**
EC (µS/cm)	593	711	658	430	598	**1000**
TDS (mg/L)	294	455	372	342	365.75	**500**
Hardness ($mgCaCO_3/L$)	117	175	145	118	138.75	**200**
Ca^{2+} (mg/L)	24	26	25	22	24.25	**100**
Mg^{2+} (mg/L)	13.4	27	20	13.8	18.55	**30**
Alkalinity ($mgCaCO_3/L$)	156	**360**	**255**	145	**229**	**200**
Na^{+} (mg/L)	1.6	2.8	2.5	1.8	2.175	**200**
K^{+} (mg/L)	0.7	1	1	1	0.925	**10**
Cl^{-} (mg/L)	14	16	15	14	14.75	**250**
SO_4^{2-} (mg/L)	77	97	87	83	86	**250**
NO_3^{-} (mg/L)	8	7.9	8	18.5	10.6	**50**
NO_2^{-} (mg/L)	0.4	0.2	0.3	0.38	0.32	**3**
PO_4^{3-} (mg/L)	1.5	1.1	1.2	1.7	1.375	**4**
DO (mg/L)	4	4.7	4.3	4.6	4.4	**5**
BOD_5 (mg/L)	2	2.3	2.1	2.5	2.225	**5**

Bold values mean more than the maximum permissible value.

Table 5: Physicochemical analyzes in Dolli Shawre spring during study period

Parameter	October	November	January	February	Mean	WHO (2004)
Turbidity (NTU)	**31**	**8**	**19**	**35**	**23.25**	**5**
pH	7.9	7.6	7.6	7.9	7.75	**6.5-8.8**
EC (µS/cm)	561	644	603	541	587.25	**1000**
TDS (mg/L)	280	412	346	285	330.75	**500**
Hardness ($mgCaCO_3/L$)	100	176	138	112	131.5	**200**
Ca^{2+} (mg/L)	31	27.5	29	35	30.625	**100**
Mg^{2+} (mg/L)	5.2	26	15.7	6.5	13.35	**30**
Alkalinity ($mgCaCO_3/L$)	138	**390**	**264**	130	**230.5**	**200**
Na^{+} (mg/L)	3.8	6.3	5	3.6	4.675	**200**
K^{+} (mg/L)	8.2	1	4.6	8.5	5.575	**10**
Cl^{-} (mg/L)	15	17	16	16	16	**250**
SO_4^{2-} (mg/L)	60	96	78	63	74.25	**250**
NO_3^{-} (mg/L)	11	14	12	18.6	13.9	**50**
NO_2^{-} (mg/L)	0.38	0.43	0.4	0.35	0.39	**3**
PO_4^{3-} (mg/L)	1.5	1.5	1.5	1.6	1.525	**4**
DO (mg/L)	**6.8**	**6.2**	**6.6**	**6.6**	**6.55**	**5**
BOD_5 (mg/L)	**5.6**	**5.3**	**5.4**	**5.1**	**5.35**	**5**

Bold values mean more than the maximum permissible value.

3.2. Calculation of CCME WQI

The CCME WQI Water Quality Index is an effective tool to evaluate spring water quality for drinking purposes. CCME WQI is used to group various parameters and their dimensions into a single score, presenting a picture of some spring water quality including (Daraban, Mam Xalan, Srukani, and Dolli Shawre) in Shawre Valley, Sulaimaniya Governorate. In this study, the overall CCME WQI of spring water samples ranged from 64.98 to 88.097 (Figure 2). The calculated CCME WQI values in this study (Table 6) were 65.00, 64.09, 88.07, and 78.45 in springs by Daraban, Mam Xalan, Sarukani, and Dolli Shawre, respectively. These values indicate that water quality can be designated as Fair, Marginal, Good and, Fair, respectively. According to this standard, water from spring Xalan is classified as "Marginal" water quality, indicating that the water from this site is polluted, whereas water from springs Daraban and Dolli Shawre is classified as "Fair" water quality, indicating moderately polluted water and unsuitable water for direct consumption without proper treatment. Furthermore, Sarukani spring water is classified as "Good" water quality, suitable for drinking and domestic use but requires simple purification treatment, such as filtration. Low CCME WQI values in Daraban, Mam Xalan, and Dolli Shawre have been attributed to high levels of turbidity, total hardness, magnesium, total alkalinity, nitrate, DO, and BOD_5. This may be due to rainwater interacting with the sedimentary rock in the area, causing ion dissolution into the aquifer (Ameen, 2019), or it might be due to inadequate waste disposal, cottage activities, large amounts of agricultural and urban run-off, sewage, over-application of inorganic fertilizer, and improper operation and maintenance of septic systems behind the spring water source (WHO, 2004), as well as the last ten years of drought, are clearly the major threats to spring water quality (Toma et al., 2013). WQI has the potential to significantly reduce pollution in a variety of spring water bodies. The analysis concluded that the spring water in the study area must be protected from contamination prior to being used for drinking and other domestic purposes.

Table 6: Calculation of CCME WQI in the studied sites during the study period

Spring sites	F_1	F_2	Excursion	Nse	F_3	CCMEWQI	Rank
Daraban	41.17	33.82	27.63	0.4	28.89	**65**	**Fair**
Xlan	41.17	38.23	24.67	0.36	26.62	**64.09**	**Marginal**
Sarukani	11.76	7.35	12.27	0.18	15.29	**88.07**	**Good**
Dolle Shawre	23.52	20.58	17.39	0.25	20.36	**78.45**	**Fair**

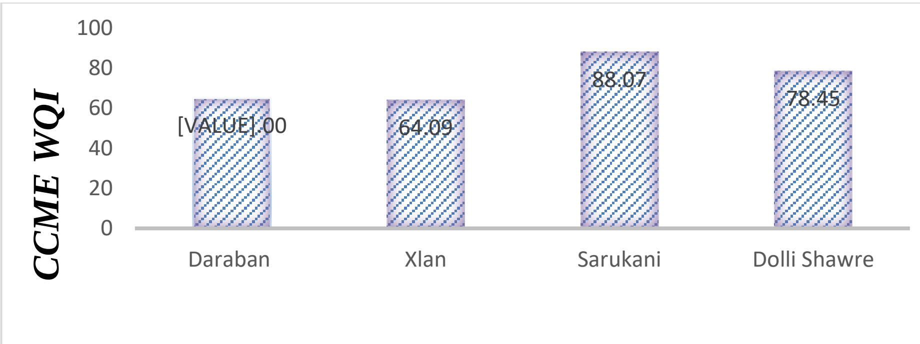

Figure 3: CCME Water Quality Index of the study sites

4. CONCLUSION:

The current study was conducted based on the CCME WQI to assess the suitability of spring water quality used by villager's people for domestic and drinking purposes in Shawre Valley, Sulaymaiyah Governorate, Iraqi Kurdistan region. It can be concluded from the analyses that the quality of spring water regarding physicochemical parameters including; pH, Ca^{2+}, Cl^-, Na^+, K^+, NO_3^-, NO_2^-, SO_4^{2-}, and PO_4^{3-}, were found to be within the allowable and safe limit set by the WHO, except for a few of them like turbidity, EC, TDS, Total hardness, Mg^{2+}, alkalinity, DO, BOD_5, in some springs were found partially within and partially above the WHO (2004) standards for drinking purposes. Generally, the overall computed CCME WQI values ranged from 64.09 to 88.07. The WQI revealed that the Mam Xalan spring at 64.00 falls under the "Marginal" category, while Daraban and Dolli Shawre at 65.00 and 78.45, respectively, fall under "Fair" quality. So such results from these spring sites are considered slightly polluted to moderately polluted and unfit for drinking. This could be due to various natural phenomena and anthropogenic activities in the catchment area during the study period. In addition, the Sarukani spring of 88.079 is of "good" quality. Based on these findings, it is feasible to conclude that these springs fall under the "unsuitable" category and require proper treatment to be fit for drinking purposes for the nearby population. Effective measures are urgently needed to prevent contaminated water from entering the springs and to improve and protect the overall water quality of these springs.

CONFLICT OF INTEREST

There are no conflicts of interest declared by the author.

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