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RESEARCH PAPER

Groundwater quality assessment for different uses using various water quality ‘indices in Shamamik basin of Erbil-northern Iraq

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A B S T R A C T:

The current study assessed the quality of groundwater in the Shamamik basin; the parameters were analyzed to determine ion distribution, classify groundwater, and identify the origin of groundwater in the study area.The EWQI of groundwater and hydrochemical parameters was based on 13 parameters including total hardness, electric conductivity,PH,TDS,Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}, T.H, HCO_3^{-}, Cl^{-}, NO_3^{-}, and SO_4^{-2} . The hydrochemical assessment demonstrated that the wells of the area studied contain more hydrochemical constituents. EC and TDS concentrations were found to be high in some wells in the studied area. According to the international standard guideline, it was concluded that the water samples collected from the wells are suitable for drinking purposes, agricultural activities as well as domestic use in the Shamamic basin of Erbil northern Iraq. The findings show that using ground water for irrigation will not harm plants because all water samples had excellent SAR for all samples, whereas RSC, with the exception of sample 1 from Tandora village, all samples are good to medium. All samples are excellent, according to PI, with the exception of sample 15 (Girdmala village), which is unsuitable for irrigation.Based on US salinity classification for irrigation 97% of the water samples presents medium quality for irrigation and can be used for these purposes without posing any danger to soil or crops.Origin of groundwater in studied are was Mg and Ca groups in both seasons and are the main contributors to the water type that Mg-Ca-HCO_3 according to Pipper1944. Mg-Ca type for both seasons based on Durove classification of groundwater type origin.

KEY WORDS: Hydrochemical characterstics; Groundwater classification ; Water Quality Assessment; and Rock-water deduction ; Shamamek Basin.
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1.INTRODUCTION:

Safe and clean water is critical for the survival of living organisms as well as the smooth operation of economies, communities, and ecosystems. (Khazri and Gabtni, 2022). Declining the quality of water has currently become a universal challenge as the population increases with an increase in agricultural and industrial activities and the effects of climatic change on the hydrological cycle (Ramos-Leal et al., 2022). Water contains naturally non-dissolved granular matter, living organisms and dissolved substances which are vital for elements of good and quality water since they assist in maintaining biogeochemical cycles (Ghorbal et a., 2021).

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Industrial and agricultural activities increase the pollution of groundwater, particularly when applying a high amount of pesticides and fertilizers during farming (Raheja et al., 2022).

Statistics show that less than 0.1% of the products used on crops reach the pest targeted and the rest are released into the environment which contaminates soil, air and water where it may poison or adversely influence organisms not targeted (Idowu et al., 2022). The quality of water in any particular area or particular water resource can be evaluated using, biological, chemical or physical parameters. These parameter values affect the health of human beings when they exceed a specific limit.

Hence, the water resources' suitability for the consumption of human beings can be explained in terms of EWQI which gives a single number that expresses a general quality of water in a specific location within a specific time depending on several water quality parameters. EWQI decreases the information bulkiness into one value to indicate the data which is logically and comprehensive to the public agencies (Ferencz et al., 2022). The activities of agriculture in Erbil city are based on groundwater with unseemly practices of farming using a high fertilizer amount and pesticides, particularly in greenhouse farming. Massive groundwater extraction, high growth of petrochemical factories and oil refineries around the farming land without any sustainability stipulations led to decreasing level of groundwater and changing chemical and physical characteristics in ways which may affect the human health and the ecosystem integrity within Erbil city.

Due to the scarcity of surface water and the absence of permanent rivers flowing, most population around this city depends on groundwater. Furthermore, most groundwater contains higher concentrations of dissolved substances than surface water as it passes under the earth's surface in different rock layers. This parameter defines the water quality as an abstract value of units and expresses the water quality for a large number of physical and chemical determinants. Therefore, this study was instituted to assess the quality of groundwater in Erbil south plain by evaluating different chemical and physical parameters available. This research was the most unique research conducted on hydrochemistry in the Shamamik basin to evaluate groundwater and suitability for human, agricultural and irrigation use by using various hydrochemical indices.

2.Study area

Shammak Basin is regarded as one of the most important basins in the Erbil governorate, which is located on the most fertile lands in the governorate of Iraq. It is considered one of the fertile basins in the Erbil governorate and has a lot of agricultural and industrial activity. According to the KRG static board (2020), the population density in the basin was about 468,736 individuals.The basin under this study situated in the Kurdistan region of Iraq (Erbil Governorate), in the upper northern region. The study area is located in the Shamamik Basin within the latitude and longitude boundaries shown in Table 1 and the map in Figure 1 shows the geographical area of the basin.

Table1: Detailed Information of the Selected Wells

No	Village	X(UTM)	Y(UTM)	Z(m)
1	Tandora/1	395410	3992610	315
2	Sorbash Ha	399135	3990615	329
3	Jadidalak	395867	3976501	364
4	Satoor	391869	4004656	441
5	Dugirdkan	405002	3981465	357
6	Helawa	390080	3980599	351
7	Tirpa Spia	403438	3984191	345
8	Minara	399257	3979683	325
9	Dukala	408079	3977733	359
10	Sirawa	389853	3991579	296
11	Gomagru	420884	3980972	446
12	Lajan	427157	3990399	655
13	Qazikhana	407235	3970745	350
14	Mirza axa	420206	3993505	528
15	Gird Mala	416388	3987621	432

UTM:*universal travers metric,**Easting** =latitude , **Northing** =Longtitude, **Z**=Elevation in meter*

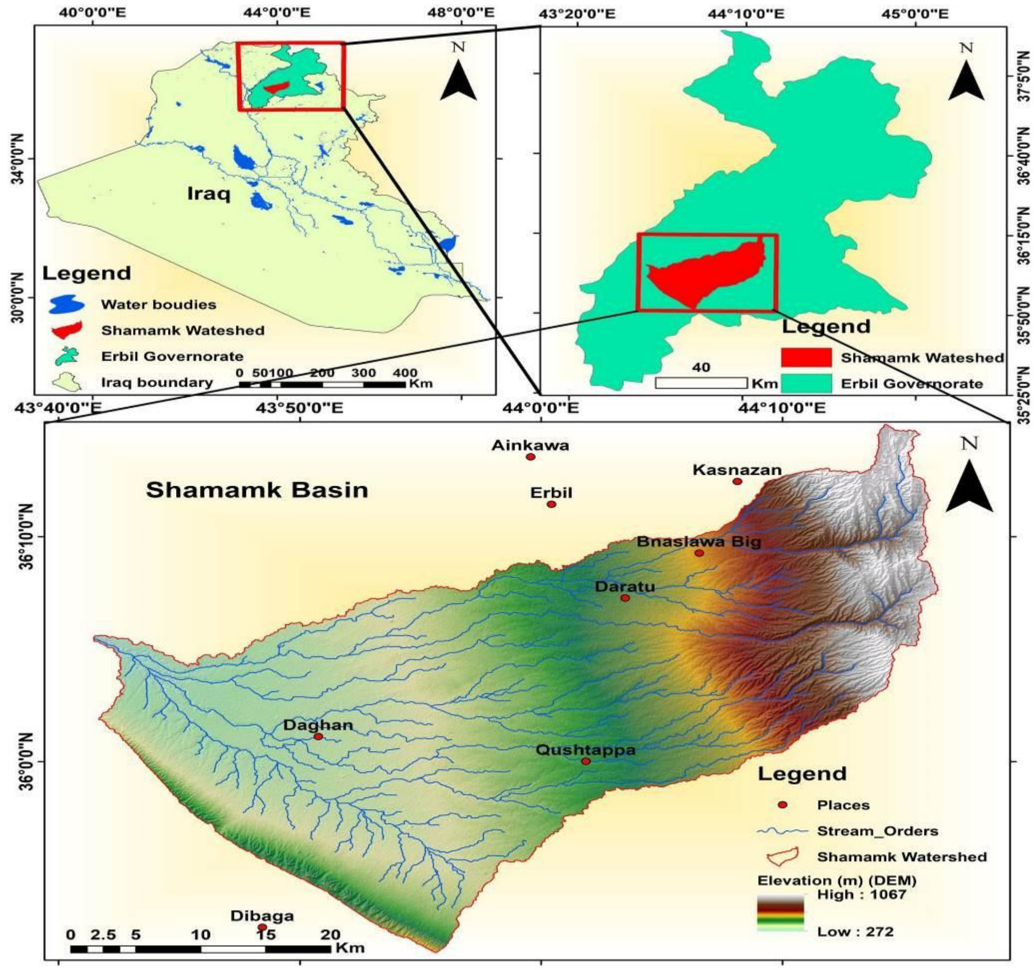


Figure 1: Degitia terrain map showing the location Shamamik basin

3.Geology of study area

The majority of the Shamamik basin is covered by Quaternary deposits, however there are a few tiny patches of Miocene-Pliocene outcrops in the east and northeast of the Sharabot-Dedawan highlands, the Avanah structure in the west and southwest, and Damirdagh in the north. The lithology of deposits varies from clay, silt, sand, and gravels (sandstone, clay stone, and conglomerate) figure 2. Deposits in the basin includes the rock units in Shamamik basin which are non-effected by Alpine orogeny consisting of clay, loam silt, sand, and gravel. Stratigraphy of quaternary deposit is unconformable with underling unit (vertically and horizontally appeared gravel alterative (repeat) coarse, medium, and fine grain size) (Abdulla et al., 2021). The age of quaternary deposits is Pleistocene to Holocene. These deposits were divided according to our field expert:

River Terrace: terraces were produced by recent flood plain exposed along each side of valley, produced by variation in base level or by climate variation in area along valley. The age is Pleistocene consisting of rock fragment limestone, fragment, gravel (silica) and little amount of igneous and metamorphic rock fragments. Flood Plain Deposits sediments originate as a result of river erosion during flood periods figure 2. They consist of clay, silt, sand, and gravel with some fine pebbles, and rock fragment. The age of this deposit is Holocene.

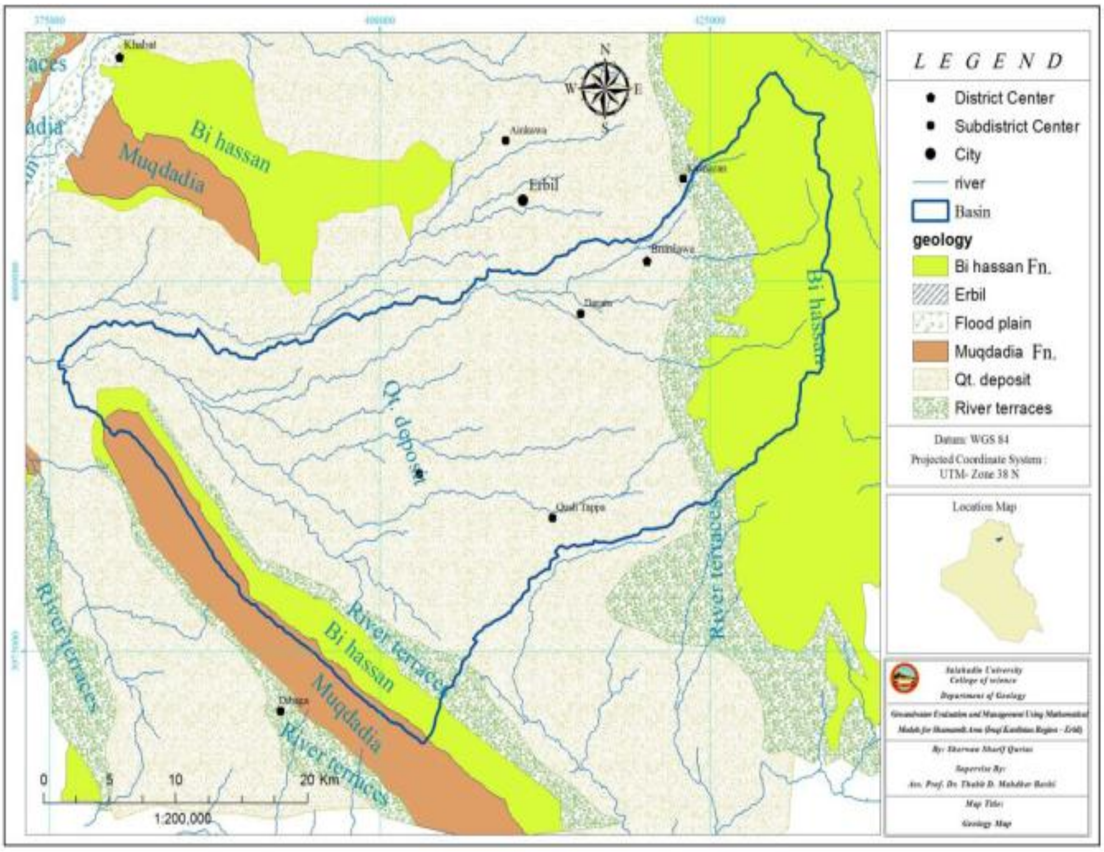


Figure 2: Geological map of study area

4.Materials and methods

4.1 Sampling Preparation and Measurement

A representative ground-water sample must reflect the physical and chemical properties of the groundwater in that portion of formation open to the well to be samples (Mohammed et al., 2020: Todd, 2005). Hydro chemical analysis of groundwater in Shamamik basin included physical, and chemical of 30 collected water samples divided into seasons Dry and wet season (Wet season in April 2022, and Dry season in October 2022) 30 groundwater samples were collected from 15 boreholes in different depth ranges between 120-300m below ground surface which is divided in two seasons wet and dry **(Table2,and3).** Turbidity, pH, and electrical conductivity (EC) of the samples were measured in the field using portable EC, turbidity meter, and pH meters. Chemical parameters such as major cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) and major anions (SO_4^{2-}, HCO_3^{-}, Cl^{-}, CO_3^{-}) were analyzed according to APHA(2012).

Na^{+} and K^{+} were analyzed using ion flam photometry instruments in Erbil water directorate laboratory. The presence of divalent metallic cations of calcium and magnesium, which are abundant in water, causes total hardness. The result of analysis are in table2and3.

An accuracy check (equation (1)) was conducted on the dataset using charge balance error (CBE). When analyzing the parameters, a charge balance error of 5% or less indicates that the cations and anions are evenly distributed (Rajab and Esmail, 2022).

$$\text{CBE} = \frac{\sum m_c|z_c| - \sum m_a|z_a|}{\sum m_c|z_c| + \sum m_a|z_a|} \times 100, \qquad (1)$$

Where mc, ma, Zc and zaare, Major cation and anion molar concentrations and cation and anion charges. Some of the statistical analyses, such cluster analysis, presuppose a normal distribution, thus the datasets were all put through normality tests. When necessary, we log-transformed and/or standardized the data to z-scores (equation (2)) to account for the fact that some datasets did not follow a normal distribution.:

$$z = \frac{x - \mu}{s}, \qquad \ldots\ldots\ldots\ldots\ldots\ldots.2$$

Where z, x, µ, and s are z-score, sample value, mean, and standard deviation, respectively .

Many researchers have utilized the WQI for similar objectives (Rajab and Esmail, 2022). The quality of groundwater for human consumption was evaluated using the same weighted arithmetic index approach as in Fayydh et al. (2020). Using this technique, parameters of drinkable water quality are given weights (Wi) according to the potential harm they provide to human health. Maximum value of 5 awarded to parameters thought to be of vital health relevance and significant influencers of groundwater quality, such as NO_3^-, and pH. According to their perceived importance in terms of groundwater transportability and health implications, TDS, TH, Ca^{2+}, Mg^{2+}, Na^+, K^+, Cl^-, and SO_4^{-2} were assigned values between 2 and 4 (Table 4). (Chegbela et al., 2020). In addition to calculating the sub-index (SI) (equation (5)) and the water quality index (WQI) (equation (6)), calculating the water quality index (WQI) required computing the relative weights (WI) (equation (8)) and the quality rating scale (qi) (equations (4)). To further categorize the calculated WQIs, we referred to the work of Sahu and Sikdar (Table 5).

$$Wi = \frac{wi}{\sum wi}, \quad (3)$$

$$qi = \frac{Ci}{Si} \times 100, \quad (4)$$

where, respectively, Ci" and Si" stand for parameter concentration" and the desired outcome. Furthermore, the sub-index (Si) and water quality index (WQI) are calculated (equations (3) and (4)), as are the relative weights (Wi) (equation (8)). To further categorize the calculated WQIs, we referred to the work of (Mukhopadhyay etal,2022) (Table 2).

In this investigation, sodium-based or -related approaches are used extensively to compare the concentration of Na^+ to that of other ions in the groundwater system and draw conclusions about the water's suitability for irrigation. Due to ion exchange, Na^+ tends to get absorbed to the surfaces of clay materials, displacing Ca^{2+} and Mg^{2+} in solution, and so reducing soil permeability, leading to poor soil structure for drainage. These factors lead to a soil type that is suboptimal for optimal crop production and development. As an instance, the sodium adsorption ratio (SAR) can be used to determine the quality of irrigation water (Fayydh et al., 2020).

While EC is used as a reference to quantify the salinity of the water, it is an index that evaluates the relative content of salt to the sum of calcium and magnesium in water used for irrigation (equation (7)).

$$SAR = \frac{Na}{\sqrt{(Ca + Ma/2)}}, \quad (7)$$

Wilcox diagrams were also used to evaluate groundwater quality for irrigation by comparing the percentage of sodium to the salinity of the water. Sodium concentration as a percentage of total major cation concentration is found using the following equation: (8). Similar to the USSL diagram, the Wilcox diagram divides suitable irrigation water into ranges based on the risks associated with sodium and salinity.

$$Na\% = \frac{Na}{Na + Ca + Mg + K} \times 100, \quad (8)$$

Where concentrations of all ions are in meq/l

4.2.Classifications and Estimation of Origins for Groundwater

Groundwater's cations and anions are a representation of the distinct physiochemical properties brought on by the groundwater's interactions with rock and soil as it moves through the aquifer. The characteristics of water bodies with various chemical compositions are represented by the aquifer. These characteristics are referred to as the hydrochemical facies of groundwater as a result.. The aquifer's rocks and groundwater flow are known to have an impact on the hydrochemical facies, and groundwater can be categorized using the Piper diagram based on the distribution of cations and anions. To categorize the samples in this investigation for each sampling period and groundwater use, we employed the Piper diagram, a key groundwater classification tool.

Moreover, the dispersionto plot the Gibbs diagram, anions (Cl^-, HCO^-), cations ($Na^{+,}$ Ca^{2+}), and the TDS value were used to infer the types of dominance, such as evapo- ration dominance, rock dominance, and precipitation dominance. Along with the Piper diagram and Gibbs diagram, the Chadah diagram was used to compare the Piper diagram in order to determine whether it could be replaced and whether it was a good fit or not.

4.2.1Piper Diagram and Durove

Anion and cation triangles that share a similar base make up piper diagrams. Two triangles' adjacent sides are 60 apart. The analyses are replotted as circles whose areas are proportional to their TDS, with a diamond-shaped space between them. One can make a rough assumption about the source of the water represented by an analysis based on where it is located on a piper diagram. Anyone who uses plots frequently is strongly encouraged to read Piper's 1944 work. The Durov diagram is a common visualization technique applied in hydrogeology to display the major ions as percentages of milli-equivalents in two ternary (trilinear) graphs that form an additional two-dimensional projection (the Durov projection)

4.2.2.Gibbs Diagram

The Gibbs diagram is used to interpret the impact of hydrogeochemical processes on the geochemistry of ground water, including precipitation, the rock-water interaction mechanism, and evaporation. The quality of groundwater is significantly influenced by the interaction between groundwater and aquifer minerals, which is helpful in assuming the origin of water. The Gibbs ratio can be calculated with the use of the following equation. Gibbs diagram for TDS and cation/anion concentration is shown in Figure 4; it is evident that most cations/anions in groundwater come from rock. To a greater extent than from precipitation or any other source, this feature shows that ions in groundwater are dissolved through the interaction of groundwater with rock or soil.

$$\text{Gibbs ratio I (for anion)} = \left(Cl^-\right)\left(Cl^- / + HCO^{-3}\right)_3 \qquad (9)$$

$$\text{Gibbs ratio II (for cation)} = \left(Na^+ + K^+\right) / \left(Na^+ + K^+ + Ca^{2+}\right) \qquad (10)$$

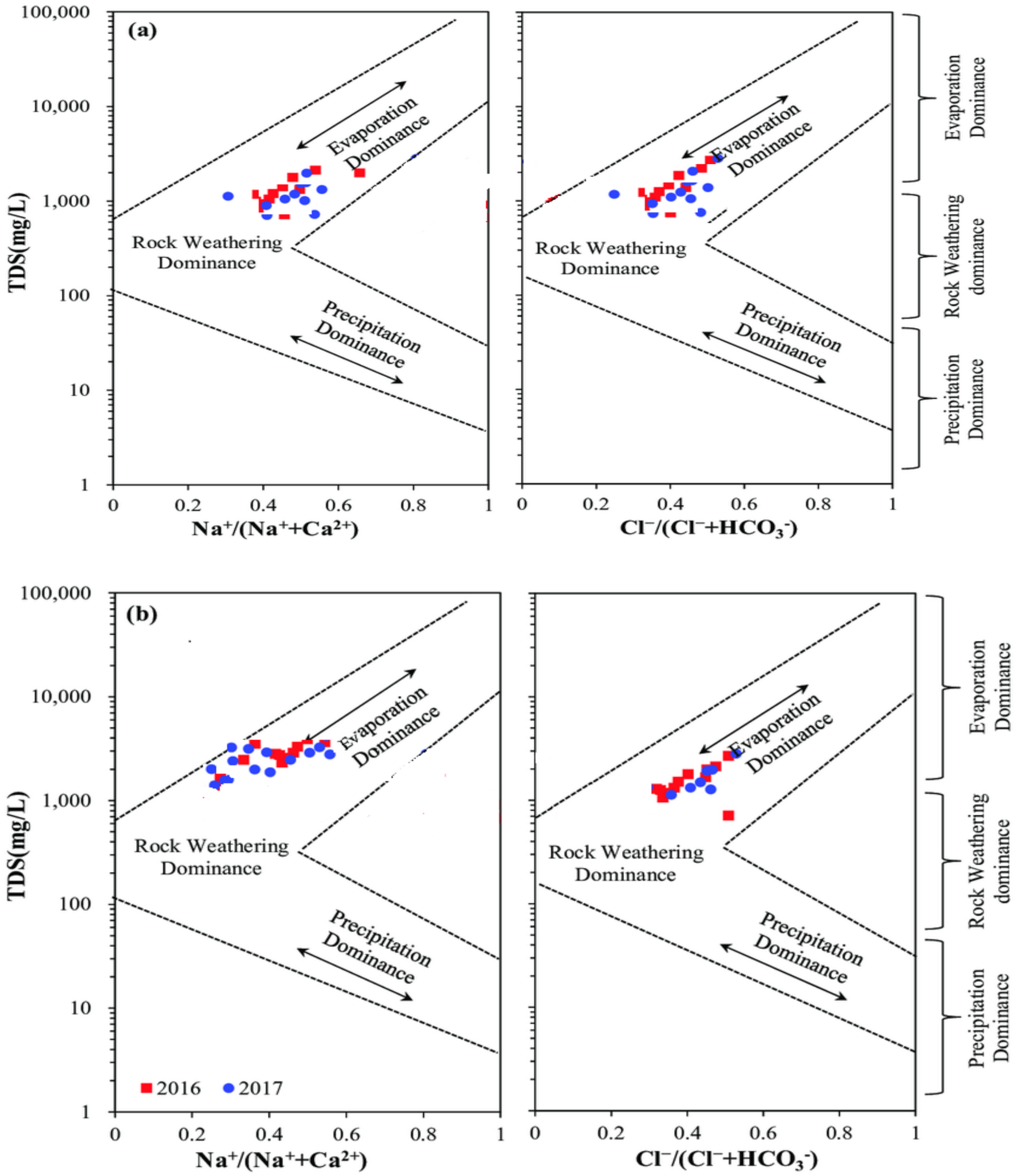


Figure4: (a) Gibbs diagram in dry season ;(b) Gibbs diagram in wet season.

4.2.3 Scholler Diagram

The classification uses semi logarithmic graph to plot the concentrations of the anions and cat ions. The concentrations are plotted in meq/L (Figure14). This type of diagram allows us to make a visual comparison of the compositions of different waters in descending order (Kumar and Bhatnagar2021) as shown in Table 2.

Table 3: Water type according to (Scholler, 1972) classification

	Cation		Anion
A	r(Na+rk)>rMg>rCa	1	$rCL>rSO_4>rHCO_3$
B	r(Na+K)>rCa> rMg	2	$rCL> rHCO_3>rSO_4$
C	rMg> r(Na+K)> rCa	3	$rSO_4> rCL> rHCO_3$
D	rMg> rCa> r(Na+K)	4	$rSO_4> rHCO_3> rCL$
E	rCa> r(Na+K) >rMg	5	$rHCO_3> rCL>rSO_4$
F	rCa> rMg> r(Na+K)	6	$rHCO_3>rSO_4> rCL$

The milliequivalent percentage differences between alkaline earths and alkali metals, and between weak acidic anions and strong acidic anions, would plot in one of the four possible sub-fields of the proposed dia- gram.

4.3. Statistical summary of hydrochemical data :

To showing the statistical analysis of chemical parameters for the 15 wells, a sample of groundwater from the wells used in the study is given in **Table 2and3**. The distribution of most parameters in the area is highly variable, suggesting that diverse processes control these parameters in an area. It is known that the pH of the groundwater affects the dissolution of minerals in the groundwater system as well affecting water quality for different purposes.

The pH in an area that doesn't show much contrast is between 8.33 and 7.14 with an average pH unit and a standard deviation of 7.735 for both seasons (Jabbari et al., 2020). Most of the highest pH values experienced in the area are outlined in figure 6. Based on figure 2 shown below, the pH of the groundwater system is neutral to the acidity with the pH ranges of natural waters falling within (4.5-8.5)(Liu,2020) . About 67% of the water samples available lies below WHO recommended standards of (6.5 to8.5) for domestic water use (Qadir et al., 2021). The majority of these high pH levels are found in the region's northernmost areas. According to equation, the leachate of organic acids from the decomposition of organic matter and natural biogeochemical processes, plant root respiration, and precipitation charged with CO_2 are the major causes of the research area's water's acidity value (1).

$4\ C_3H_7O_2\ NS+\ 8\ H_2O \rightarrow 4\ 4CH_3\ COOH\ +4NH_3\ +4H_2S$………. (1)

The EC and TDS readings are within the updated WHO criteria for drinking water, which are 2500 S/cm and 1000 mg/L, respectively (Othman and Ibrahim, 2021). Rainwater seeps into the ground and moves through a rocky layer beneath the surface, dissolving minerals and transporting dissolved particles in its wake. As a result, the TDS values are normally highest at drainage sites after having traveled through the centre of the rock and traditionally dissolving more material along the fluorescence path than at infiltration points, which are intended to recharge areas. Water dissolves more minerals, which results in a greater availability of electrolytes and ions in groundwater systems and a higher EC value (figure 5).

The EC values The extent to which something may be attributed to the influences of geology or human activity varies substantially (Othman and Ibrahim, 2021). HCO_3 is also shown at a rate of 166.50 mg per liter, with a minimum value of 20 mg/L and a high of 310 mg/L. HCO_3 exhibits a positive line relationship with pH, rising at higher pH levels and falling at lower pH levels. Bicarbonate is the main anion in pH ranges of 4.5 to 9 in natural water systems (Jwan et al., 2021). Bicarbonate was therefore the dominant anion in the groundwater system within the specified pH ranges. Ca^{2+}, Mg^{2+}, Na^{+},CI^{-}, SO_4^{-2}, and NO_3^{-} are other parameters that exhibit large variations and divergence from indicates that the readings are within the World Health Organization's permitted range. According to figure 5, it appears that most of the metrics for home water use are skewed.

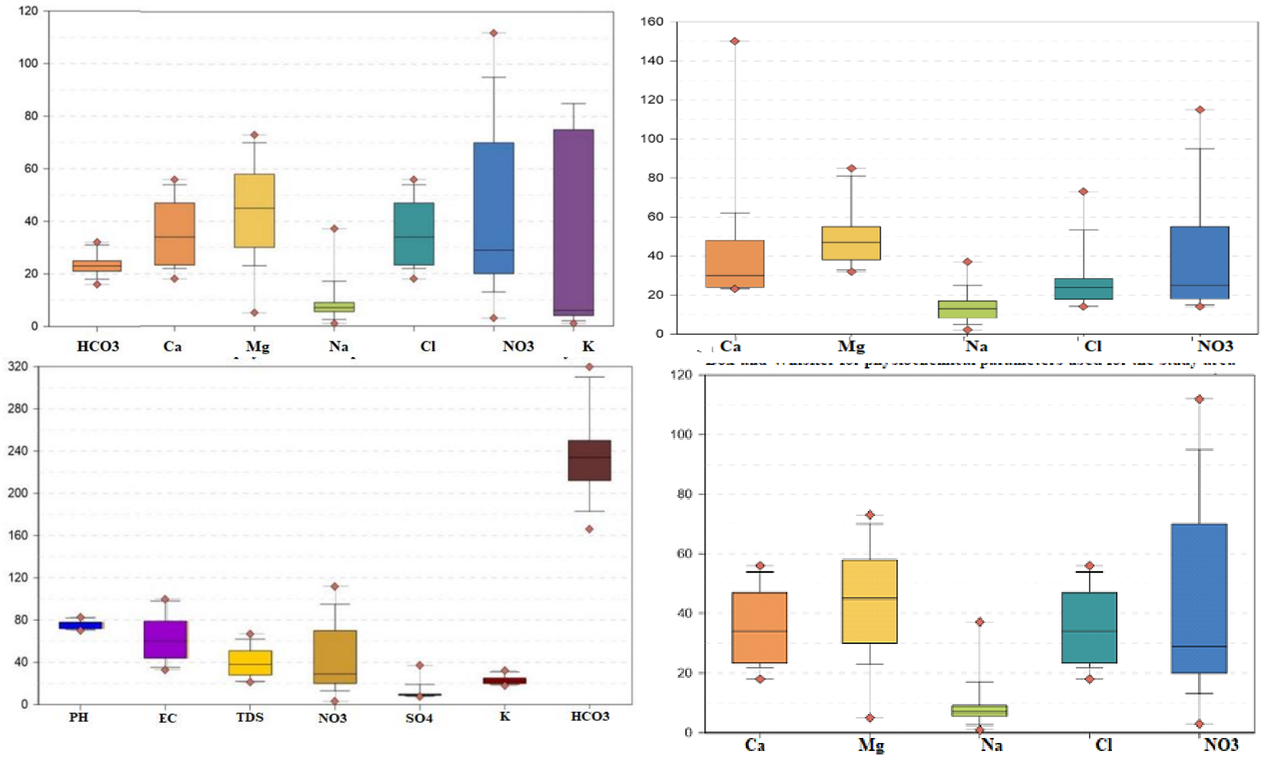


Figure5:Box and whisker statocal analysis for both season ;(a) wet season,(b) dry season

4.4.Major Controls in Groundwater Chemistry

The correlation coefficients for the various parameters analyzed were calculated as a basis to make some inferences and draw relationships between parameters to a large extent range, and predict the values of other parameters in places without actually measuring it (Abdulla et al., 2021). Pearson's link The modulus (y) ranges from -1 to 1, where 1 and 1 are perfect Inverse correlations and perfect direct correlations pH showed a significant correlation with TDS ,Ca^{2+}, Mg^{2+}, Na^{+}, HCO_3^{-} and Cl^{-}. Among these, pH and HCO^{3} Show the highest correlation (p - 0.320) with HCO_3 significantly increases with increasing in pH value.

The interaction with pH suggests that these ions may release or dissolve in liquids when the pH value changes. Bicarbonate is also closely related to EC, TDS, Ca^{2+}, Mg^{2+}, and Na^{+} .
Due to the potential dissolution of minerals including calcite, dolomite, and aragonite that are found in vehicle bonnets, the Ca-Mg-Na-HCO_3 system is likely to be dominant in the water type. However, because it exhibits connection with EC, TDS, Ca^{2+}, Mg^{2+}, HCO_3^{-}, and high linearity Relationship with SO_4^{-2}, the disintegration of silicate minerals and the relationship between F and other parameters is not well created.

5.Results and discussion

5.1Physical and Chemical parameters

In this study found a deterioration of the quality of the studied water sources according to the EWQI values since it was of poor quality or very poor water when used for drinking because of the high concentrations of some ions such as calcium, which gives water unpleasant taste and sulfate ions give water a bitter taste and causing diarrhoea. The groundwater quality status in the area of study which was considered critical was that out of the 13 various parameters used in the assessment, about 12 of them were above the allowed levels that achieved WHO standards for drinking. The EWQ outcomes show that the groundwater studied was within a weak level which requires purification and treatment before utilizing it for domestic purposes. Additionally, the hydrogeochemical analysis of wells for dry and wet seasons revealed that all water samples have low turbidity values.

In current study pH of groundwater samples ranged between 7 and 8.03, with a mean pH of 7.6 (table2 and3). The water samples' TDS readings ranged from 212 ppm to 673 ppm with mean 400 to 325 mg/l (table2 and3). The electrical conductivity of water samples indicates that the water is highly to excessively mineralized. (TDS 1000 ppm) All water samples are regarded as being of the fresh water type. In the water samples from the study location, the calcium ion is the predominate primary cation. The levels of Ca^{2+} varied from 18 ppm to 56 ppm. Na ranges from 4.5 to 43mg/l is due to anthropogenic source leakage effects on groundwater quality, certain water samples have excessive Na concentrations. The investigated water samples had bicarbonate values ranging from 183 to 320 ppm (table2 and3). The Shamamik basin and the area around it have the highest positive bicarbonate anomalies by direct effect of carbonate contenet in aquifer soil. Additionally, the direction of groundwater movement raises bicarbonate ion concentration.

Sulfate levels in water samples from the study area varied from 50 ppm to 138 ppm (table2 and3); the highest concentration was thought to be from agricultural fertilizers and sewage infiltration as they are located in the basin. High concentration of NO_3 and Cl was attributed to effects of anthropogenic source and urbanization especially in groundwater samples1,2and12. While the majority of the groundwater use in the area is for household and drinking purposes, specific chemical characteristics that have significant health consequences are further examined to guarantee that the groundwater is suitable for use in the area. It is typical for the pH distribution in the area to range from 7.13 to 8.33 (Jabbari et al., 2020). The water uses for drinking purposes depend on ionic concentrations (major cations and anions), trace element, total dissolved solid, chemical and biological properties. Drinking water must be empty from organic matter, chemical, biological, harmful material which affect on human health and had a good taste and odor (Todd,2005).

The drinking water quality of Shamamik basin determined by comparing it with the IRS (2011), WHO (2012), (Table 4).Based on physical constituent are suitable for drinking ,while based on chemical parameters such as Ca^{2+}, Mg^{2+}, Na^{+}, K^{+} and major anions SO_4^{2-}, HCO_3, Cl, NO_3) are can be use except wells 1,2,5,10, and15 due to high concentration of nitrate and chloride.

Table2:Physiochemical parameters in groundwater for wet season (April ,2022)

No	Turbidity NTU	pH	EC µ S/cm	T.D.S mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Hardness mg/l	Alkalinity mg/l	CL mg/l	NO_3 mg/l	SO_4 mg/l
1	0.312	7.68	969	620	34	54	35	1	302	212	67	78	51.26
2	0.481	7.72	661	423	47	73	28.5	0.75	420	273	56.8	70	115.78
3	0.312	7.16	632	417	41	63	22.3	0.51	317	210	43	42	138
4	0.923	8.1	355	227	18	54	13	0.75	269	220	21.3	19	67.72
5	1.11	7.67	837	536	42	70	30	1.2	392	313	52.25	59	78.12
6	0.17	8.21	797	510	25	36	10	0.6	210	203	31.95	28	72.00
7	1.79	7.88	443	283	23.3	23	4.5	0.72	156	183	14.2	3	97.00
8	1.05	7.62	481	308	34	45	10	0.6	271	259	35.2	29	54.00
9	1.03	7.73	753	482	40	37	22	0.71	207	217	56.8	32	81.00
10	0.376	7.89	1051	673	23.3	49	17	0.85	260	234	62	112	70.00
11	0.421	7.77	332	212	22	33	8.5	0.23	195	202	14.2	13	51
12	1.15	8.33	419	268	27	58	43	0.95	307	230	71	95	78.00
13	0.1	7.14	561	359	56	5	22.2	0.6	250	195	19	21	51.00
14	0.2	7.21	532	340.5	54	30	19.7	0.6	260	255	14	23	50.70
15	0.1	7.32	604	386.6	53	29.88	37.4	0.6	257	320	23	20	93.00
Min	0.1	7.14	332	212	18	5	4.5	0.23	156	183	14	3	50.7
Max	1.79	8.33	1051	673	56	73	43	1.2	420	320	71	112	138.9
Average	0.635	7.695	628.5	403	35.97	43.99	21.54	0.711	271.5	235.1	38.78	42.93	80.03

Table3:Physiochemical parameters in groundwater for dry season (October ,2022)

	Turbidity NTU	pH	EC µ S/cm	T.D.S Mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Hardness mg/l	Alkalinty mg/l	CL mg/l	NO_3 mg/l	SO_4 mg/l
1	0.403	7.94	554	355	42	48	17	0.85	301	212	24.85	60	79.65
2	0.53	7.66	761	487	30	85	37	0.85	426	234	53.25	55	188.5
3	0.635	7.88	485	310	24	47	8.8	0.4	255	246	21.3	25	102
4	0.245	8.17	316	202	24	38	8	0.6	216	217	17.75	17	97
5	0.253	7.89	748	502	48	65	25	0.75	388	310	24.85	95	73.13
6	0.906	8.13	369	253	30	81	8.1	0.5	410	261	17.74	18	166.8
7	0.2	7.74	430	275	23	47	12	0.23	250	250	35.3	15	100
8	0.365	7.98	475	304	35	55	13	0.75	313	215	24.75	22	109.5
9	0.498	7.96	595	381	29	51	11	0.4	284	240	28.4	40	87
10	0.23	7.25	393	252	23.3	40	13	0.5	228	230	21.3	28	91
11	0.489	8.23	326	208	23.3	32	17	0.6	191	211	14.2	14	89
12	0.682	7.82	594	380	58	51	2	0.6	355	320	73	115	88
13	0.4	7.32	479	306.6	150	44	14	0.1	188	183	24	18	372.6
14	0.3	7.33	480	307.2	48	32.88	5	0.2	257	166	14	19	90.96
15	0.1	7.14	558	357.1	62	33.36	18	0.3	294	236	17	30	85.15
Min	0.1	7.14	316	202	23	32	2	0.1	188	166	14	14	73.13
Max	0.906	8.23	761	502	150	85	37	0.85	426	320	73	115	372.6
Average	0.416	7.763	504.2	325.3	43.31	50.02	13.93	0.509	290.4	235.4	27.45	38.07	121.3

Table4: Standard guideline properties for drinking water compared with physical chemical component for Shamamik groundwater.

Parameters	WHO (2012)	IRQ (2011)	Seasons					
	mg/l	mg/l	Wet season (April 2022)			Dry season (October2022)		
			Min	Max	Average	Min	Max	Average
Ca^{+2}	75-200	50	18	56	35.97	23	150	43.31
Mg2+	50-100	50	5	73	43.99	32	85	50.02
Na+	200-250	200	4.5	43	21.54	2	37	13.93
K+	10-12	10	0.23	1.2	0.711	0.1	0.85	0.509
Cl-	250	250	14	71	38.78	14	73	27.45
SO_4^{-2}	250	250	50.7	138.9	80.03	73.13	372.6	121.3
NO_3	50	50	3	112	42.93	14	115	38.07
T.H	-		156	420	271.5	188	426	290.4
TDS	1000	1000	212	673	403	202	502	325.3
pH	6.5-8.5	6.5-8.5	7.14	8.33	7.695	7.14	8.23	7.763
Turbidity	5NTU	5NTU	0.1	1.79	0.635	0.1	0.906	0.416
EC	1500	1500	332	1051	628.5	316	761	504.2
Alkalinty	250	250	183	320	235.1	166	320	235.4

5.2. Water Quality Index Assessment for Drinking (WQI)

Furthermore, the collected data was analyzed Using standard analytical methods (APHA, 1998) where 22 water parameters were taken into account to calculate the water quality index (Jabbari et al., 2020). The calculated unite weight (wi) values of each parameter are given in Table 4. If quality rating qi = 0 means the complete absence of pollutants, While 0 < qi < 100 implies that, the pollutants are within the prescribed standard.

Table 4: Drinking water standards and unit weight of the water quality parameters

Parameters	Unit	Water quality standards	Unit weight
NO3	mg/L	50	0.02
Alkalinity	mg $CaCO_3$/L	200	0.005
Hardness	mg $CaCO_3$/L	200	0.005
Mg	(mg/L)	30	0.03
Ca	(mg/L)	100	0.01
Na	(mg/L)	200	0.005
K	(mg/L)	10	0.001
T.D.S	(mg/L)	500	0.002
EC	µS/Cm	1000	0.001
pH		6.5-8.5	0.130

Groundwater quality is determined by computing values of water quality indices, which takes into account the interconnectedness of numerous physicochemical characteristics that affect drinking water quality as a whole. Some basic presumptions were developed to evaluate water quality in light of several studies on water pollution: (Jesuraja et al., 2021). For these calculations, we used the following thresholds: EWQI 50 for potable water; EWQI and EWQI >100 for unusable water. Table (6, 7)

Table 6: Water quality types for both season in studied area

Wet season (April)		Dry season(October)		
location	**EWQI**	**Location**	**EWQI**	**Water Quality status**
Tandora/1	88.45	Tandora/1	82	Very poor
Sorbash Ha	99	Sorbash Ha	101.8	Unfit for consumption
Jadidalak	87	Jadidalak	74	Very poor
Satoor	76	Satoor	67.4	Poor
Dugirdkan	95.49	Dugirdkan	99.5	Very poor
Helawa	68	helawa	92.6	Very poor
Tirpa Spia	56	Tirpa Spia	72	Poor
Minara	74	Minara	78	Very poor
Dukala	70	Dukala	799	Poor
Sirawa	91	Sirawa	70	Very poor
Gomagru	63.8	Gomagru	63	Poor
Lajan	92.7	Lajan	96.1	Very poor
Qazikhana	53.4	Qazikhana	77.8	Poor
Mirza axa	66.85	Mirza axa	66	Poor
Gird Mala	67.3	Gird Mala	70	poor

Table 7: Drinking water quality parameters (EWQI)

Water Quality Index	Water Quality status
0-25	Excellent
26-50	Good
51-75	Poor
76-100	Very poor
>100	Unfit for consumption

According to water quality index sample 1,3,5,6,8.10,and12 are very poor ,while sample 4,7,9,11,13,14,and 15 are poor ,and sample 2for dry season indicate to unfit for consumption accroding to water quality index.Figure6 show spatial distribution of water quality index(EWQI) for both season in Shamamik basin it is clearly the west part of the basin are higher than east part due to effect downstream movement of groundwater and anthropogenic source. Fluctuation between wet and dry season is attributed to climate (dry) season, soil and geological formation of studied area a

b

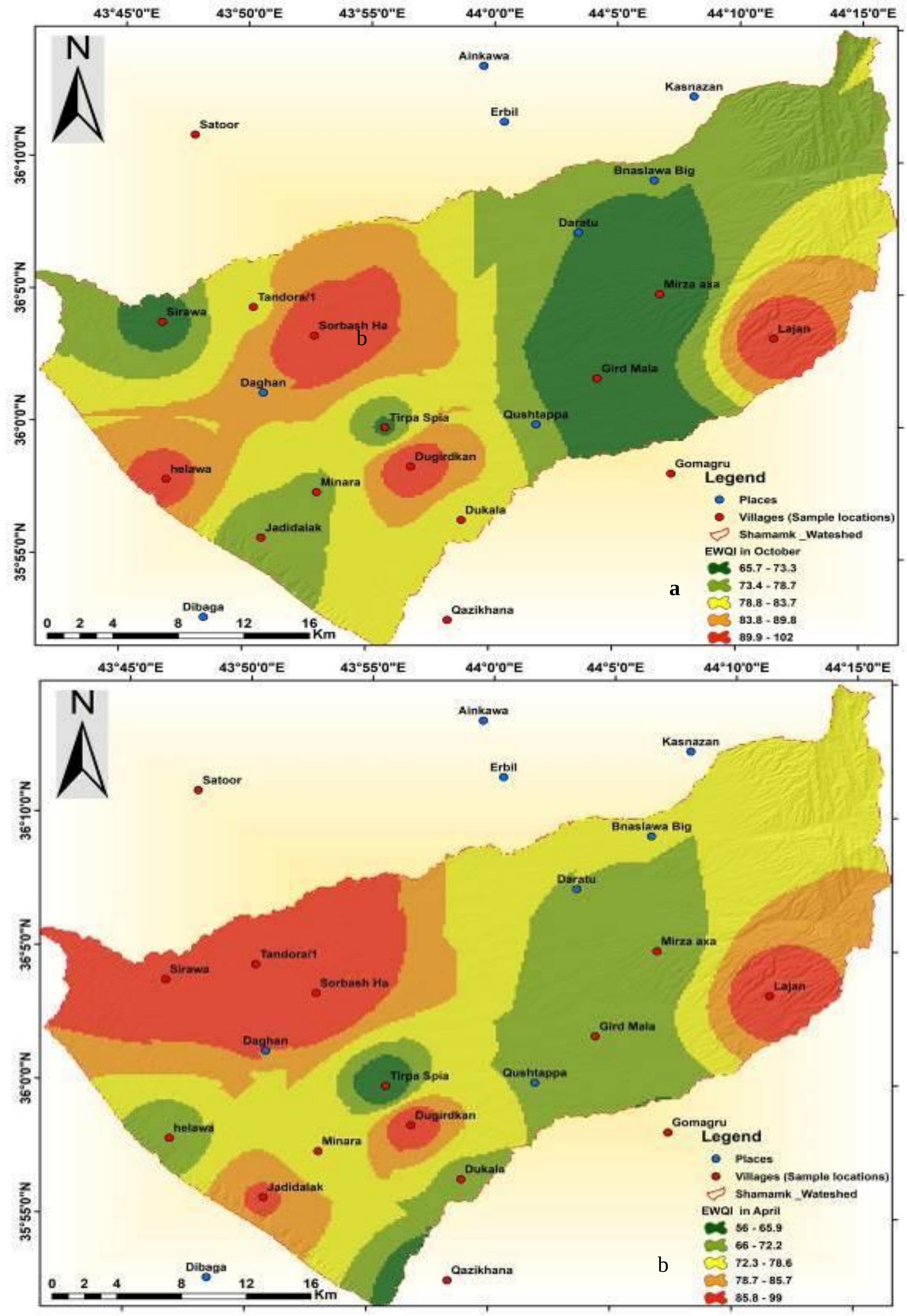


Figure 6:WQI spatial distribution in Shamamik basin ;(a)wet season,(b)dry season.

5.2.1Finding an entropy-weighted water quality coefficient (EWQI) for drinking and irrigation purposes:

The calculation of the groundwater quality coefficient is necessary to determine the specifications of this water and the degree of its suitability for use due to the lack of liquefied water in the study area. The EWQI is evidence that reflects the impact of the various studied standards on water quality.The assessment in the table 5 shows that the water quality factor for drinking purposes for some water sources in the region of study where it was under poor or very poor class and needs treatment before use, which can be due to the rise of cations and anions, especially Sulphate ions and dissolved salts, which are due to the nature of the geological area, and these factors contribute to a decline in the sensitivity function's value, which is used to calculate the water quality factor, and a consequent decline in the quality of the water.

The groundwater quality indices were evaluated to identify its suitability for drinking purposes based on the chemical and physical characteristics of groundwater which indicated the potable water quality level in the underground resources of the area studied. This assessment found that villagers and farmers could not utilize groundwater directly for domestic use because sometimes it leads to disease and inflammation, particularly for children. This finding was similar to the Mohammed et al, (2020) finding.

5.3.Water Quality Assessment for irrigation Usage

Groundwater's suitability for irrigation is primarily determined by its sodium content (Na (%)), sodium adsorption ratio (SAR), residual sodium carbonate (RSC), permeability index (PI), and permeability) (RSC). As a results of applying the equations and classifications for evaluating of groundwater all above classification limits are in table8 .To assess the quality for irrigation and agriculture we use dry period samples due less variation inconcentration from wet to dry peroid.Based on SAR all samples are excellent table8,same as for Na% are excellent for all samples table8,while according to RSC except samples 1 from Tandora village are unsuitable (Bad) all samples are good to medium table9.According to PI all samples are excellent except sample 15(Girdmala village) was unsuitable for irrigation table8.

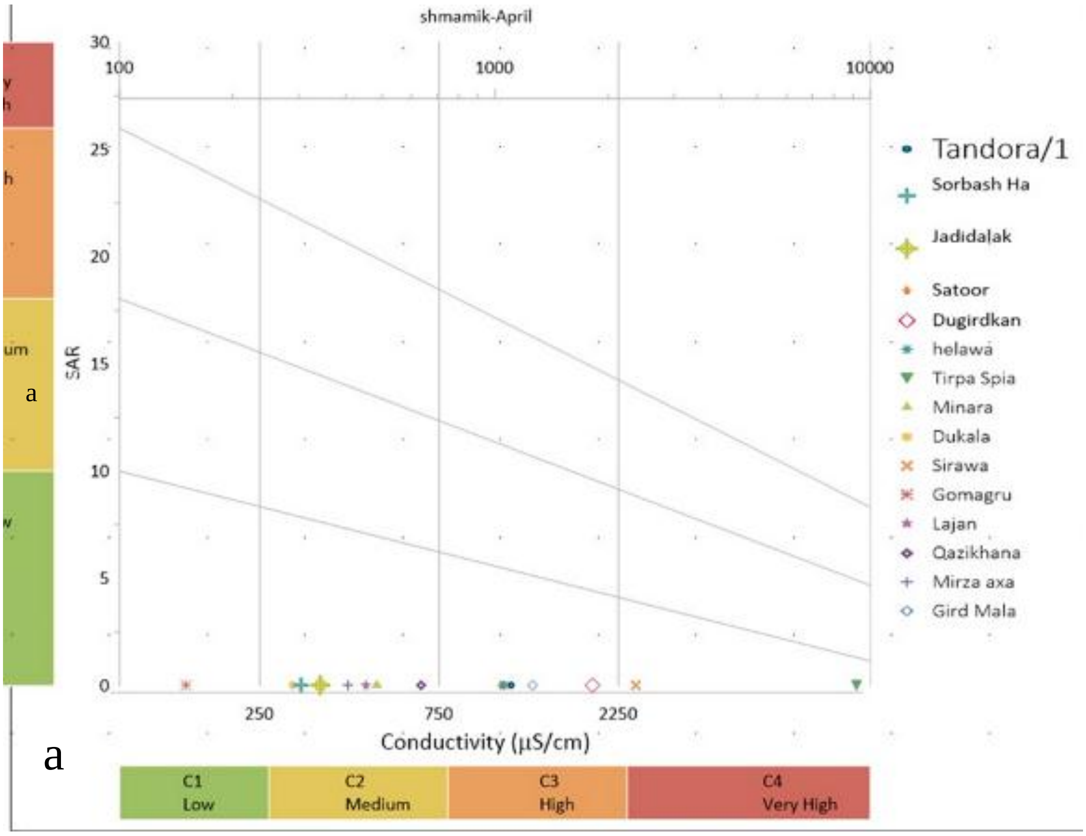
Table 8: Classifications of groundwater by SAR, Na (%), RSC, PI.

	SAR		Na (%)		RSC		PI	
	10 - 20	Excellent (E)	Up to 20	Excellent (E)	<1.25	Good/Safe (G)	>75%	Excellent (E)
Classification	10 - 18	Good (G)	20 - 40	Good (G)	1.25 - 2.5	Medium/Marginal(M)	25 - 75%	Good (G)
of assessment	18 - 26	Fair (F)	40 - 60	Permissible (P)	>2.5	Bad/Unsuitable (B)	>25%	Unsuitable (U)
	>26	Poor (P)	60 - 80	Doubtful (D)	-	-	-	-
	-	-	>80	Unsuitable (U)	-	-	-	-

Table9:SAR,Na%,RSC,and PI concentration in Shamamik basin groundwater

Village	SAR	Na%	RSC	PI
Tandora/1	0.34218	5.186801594	2.803723361	50.77467
Sorbash Ha	0.557337	0.330719792	1.200409836	60.30551
Jadidalak	0.142731	0.190498188	2.211065574	76.46136
Satoor	0.127112	0.136096014	2.132786885	117.9727
Dugirdkan	0.443871	0.108894928	2.257377049	154.9235
Helawa	0.124376	0.108894928	2.481967213	136.6995
Tirpa Spia	0.208625	0.217699275	2.253688525	97.7377
Minara	0.227816	0.136096014	2.852527322	131.5464
Dukala	0.2163	0.104361413	1.428756831	164.2678
Sirawa	0.193879	0.158763587	2.363592896	92.9797
Gomagru	0.320912	0.1315625	2.30840847	125.1496
Lajan	0.045335	0.105721467	2.19693306	149.2111
Qazikhana	0.17912	0.105721467	2.104234973	136.9125
Mirza axa	0.094997	0.26303442	1.125	83.54419
Gird Mala	0.305547	0.680117754	0.121311475	18.73333

This study employed a US salinity laboratory's semi-logarithmic plot of SAR against EC to assess the quality of irrigation water. A graph showing how irrigation water is categorized as having a salinity hazard that ranges from low to extremely high on the EC axis and a SAR axis. According to this categorization, all groundwater samples in the region were classified as having a depression viscous class in shape, a lowered in low class, and a single average salinity class.The samples are located as in (figure7**)**. So, About 97% of the water samples presents medium quality for irrigation and can be used for these purposes without posing any danger to soil or crops. This confirmation however, depends on the initial soil conditions like Soil containing excess sodium and/or salinity should be treated .



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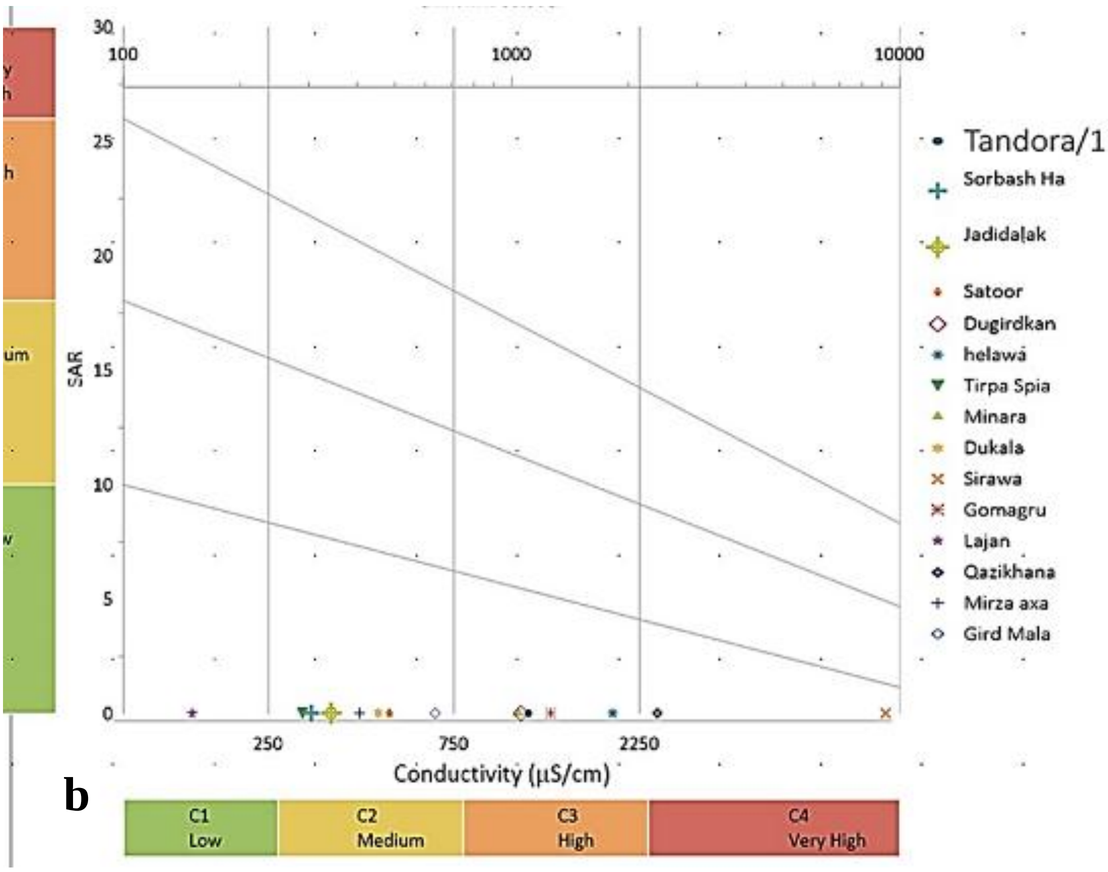

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Figure7: Wilcox diagram showing classification of groundwater based on sodium hazard and salinity;(a) wet season.(b)dry season

5.4.Water Quality Assessment for Agricultural and irrigation Usage

Tolerance of crops is different for concentration of EC, and depending on Todd 2005 Table10 represents suitablity of studied groundwater samples in Shamamik basin all water samples are in lowe salt tolerance of crops to different salinity with comparison to studied groundwater samples which are suitable for agriculture with particular type of crops. Figures 8represent EC fluctuation in two seasons in Shamamik basin.

Table 10: irrigation water salinity tolerance for different crops (Todd, 2005)

Crop division	**Low salt tolerance**	**medium salt tolerance**	**High salt tolerance**	**Water in the studied area**	
				wet period	**dry period**
fruit	0-3000 µs/cm Avocado, lemon, Orange, apple Strawberry, picot Prune, plum	3000-4000 µs/cm Olive, date, fig Cantaloupe, pomegranate	4000-10000 µs/cm palm	332 -1051 µs/cm	316 -761 µs/cm
vegetable	3000-4000 µs/cm Green bean, celery Radish,	4000-10000 µs/cm Cucumber, onion, peas Carrot, potato, cauliflower Lettuce, squash	10000-12000µs/cm Spinach, kale Asparagus,		
Field crops	4000-6000 µs/cm Field bean,	6000-10000µs/cm Sunflower, corn, rice Flax, castor bean, corn wheat	10000-100000µs/cm Cotton, sugar beet, barley		

The EC value during wet(April) period ranged between 332 – 1051 µ s/cm .The low value recorded in north east of basin, while the high value recorded in midle part of the basin (Table 2 and3) and figure8. EC value in dry(October) period ranges between 316 – 761 µ s/cm, low value are recorded in comparing with wet peroid (Table 2and 3) and figure8. No significant variation noticed during two periods in EC values .

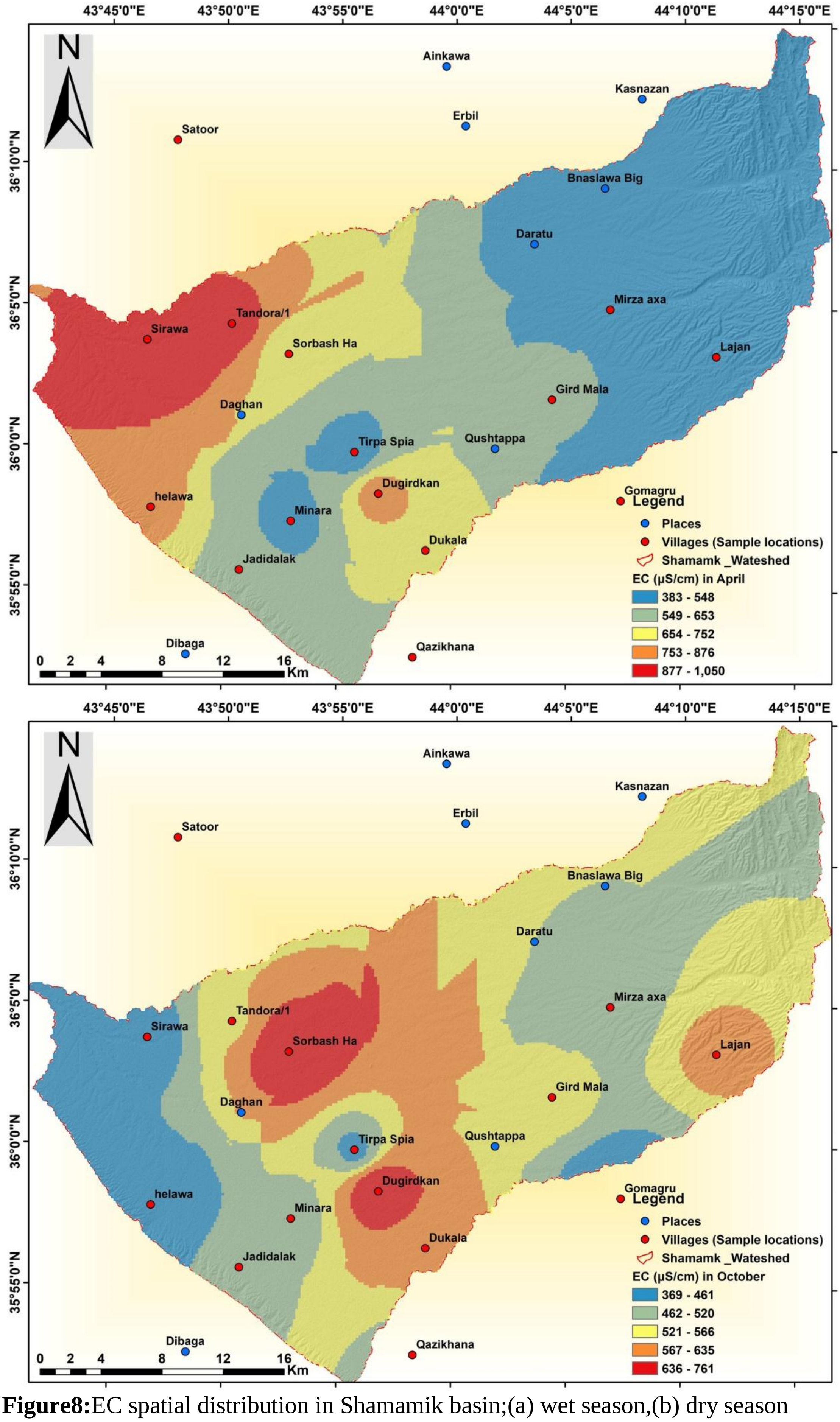

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Figure8:EC spatial distribution in Shamamik basin;(a) wet season,(b) dry season

The local groundwater is typically a sort of hard water that is used for portable and domestic purposes. TH and cardiovascular disease have an antagonistic association, unlike what the World Health Organization claimed Hard water locations are more likely to experience crust buildup in piping, storage tanks, and water treatment systems when TH levels are higher than 200 mg/L. (Bapir et al., 2020). The groundwater in the area is of unsatisfactory quality, according to the Water Quality Indicator Approach used in this study, which classifies all water samples as being in the "not good" category and having excessive lead levels.

5.5.Hydro chemical parameters General Hydrogeochemistry

The group (figure9,10,and11**)** for both seasons also presents poor mineralization Groundwater, which is characterized by relatively low levels of Principal ion concentration, which is a feature of the regions of the flow system, may be the result of velocity or the result of the short period of residence in the geological material in which it is found. Low pH conditions shown for CA-1 also create a favorable environment for miniature rocks. The groups show relatively medium to high mineralization in the rest group .Figures 9, 10,11 show residence time and interaction between groundwater and rocks as the water moves from the feeding areas to the drainage areas. It seems that the total content of dissolved ions increases with increasing Freshwater type, and evolutionary sequence is observed. The groundwater flow regime in particular does not appear to follow the evolutionary sequence as described by Chebotarev Hawez et al. (2020), which suggests a decrease and an increase in HCO3 concentrations - and Cl, respectively, in the discharge regions.

This suggests that there are variable sources of HCO_3 in the groundwater system in the study area. The diffusion of Mg-Ca ions in the solution, which implies the replacement of Na + with either of them, explains the reverse ion exchange. These types of alkaline earth water predominate in the groundwater system due to Ca^{+2} + or Mg^{+2}. The groundwater system, which is dominated by sodium ions, can reverse ion exchange when Ca^{+2} and Mg^{+2} are present (figure 9). The ions, which are typically connected to clay, can replace calcium or magnesium ions when there is sodium (Mawlood, 2019). During this process, change in the composition of water, seems to be an important process in groundwater system in the district**.** Dissolution of dolomite released appears that Mg^{2+} and Ca^{2+} in solution is a Large carbonate weathering process in groundwater system, while the dissolution of gypsum results in Ca^{2+} and Corner 4 2− especially in feeding areas, where there is a bedrock exposed (Hamad, 2022).

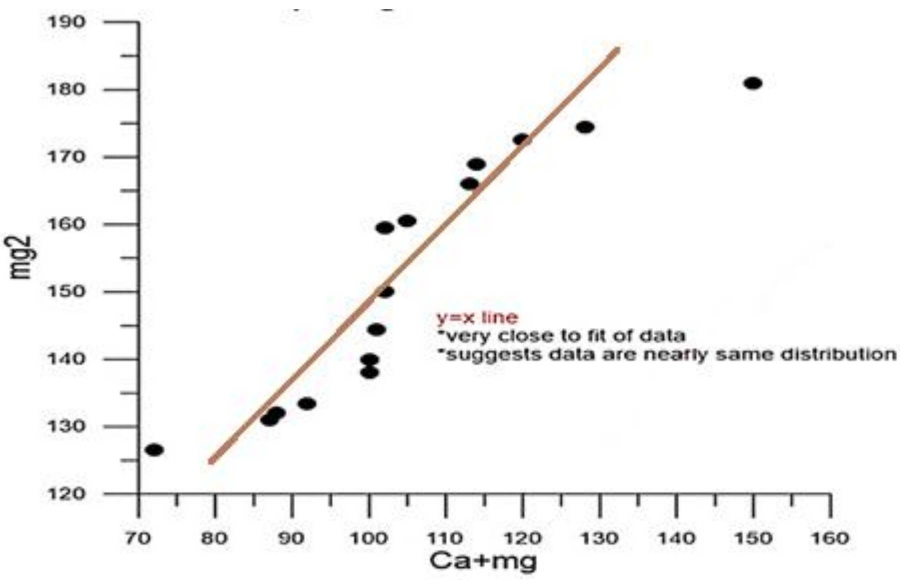

Figure 9: Ca^2 / $Ca^{2+}Mg^2$) diagram for dolomite weathering type

Generally, group samples for the two seasons are acidic. The pH values affect the minerals, and thus lead to an increase in TDS with a correspondingly higher pH. Hence, the gallery is relatively medium, high pH and TDS, respectively.

Calcium and Magnesium can also be the origin of Understood by the plot of Ca^{2+}+Mg^{2+} vs. HCO_3^-

(Fig. 9 and10). Molar ratio value for $(Ca^{2+}+Mg^{2+})/HCO_3$ - Carbonate/Silicate mineral weathering suggests that as a major source of Mg^{2+} and Ca^{2+} in groundwater, it is mainly affected by carbonic acid. For some samples, it increases in neighborhood from feeding areas to drainage areas, with Corresponding rise in pH, indicating ion exchange as a control agent for the aqueous chemistry of these samples.Figure 9 confirms that some levels of ion exchange Between Ca^{2+}, Na^{+}, and Mg^{2+} as a contributing factor to Hydrochemistry as a plot of $(Ca^{2+}+Mg^{2+})-(SO_4^{2-}+HCO_3^{-})$opposite $Na^{+}+K^{+}-Cl^{-}$ was used to evaluate this phenomenon. A piece of these two indicators gives a slope from −1, as the samples were drawn away from Origin, indicates the possibility of significant effects of the ion Exchange in the groundwater system while the slope deviates significantly from -1 and clusters originally indicate otherwise.

The plot of Na + vs. Cl suggests that the opposite dominates the ion exchange Cation exchange and possibly the Na+ weathering mineral. (figure10). Affirmations confirms that Durov plot (figure13) is Partially based on the fact that halite dissolution does not calculate sodium ions in groundwater and the dominance of sodium ions over chlorine ions Chemical processes are better understood through the possible Weathering of gypsum **(figure11)** and dolomite **(fogure9)**.

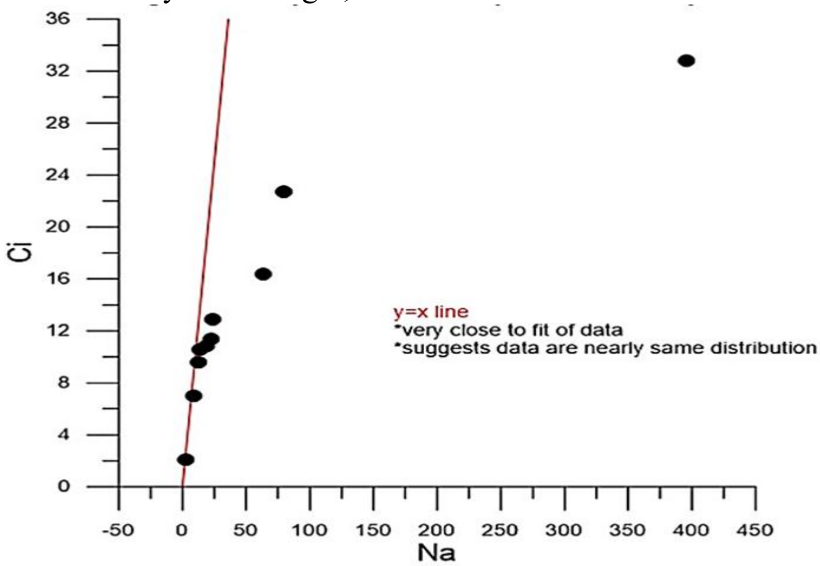

Figure 10: Na vs. Cl diagram for hallite weathering

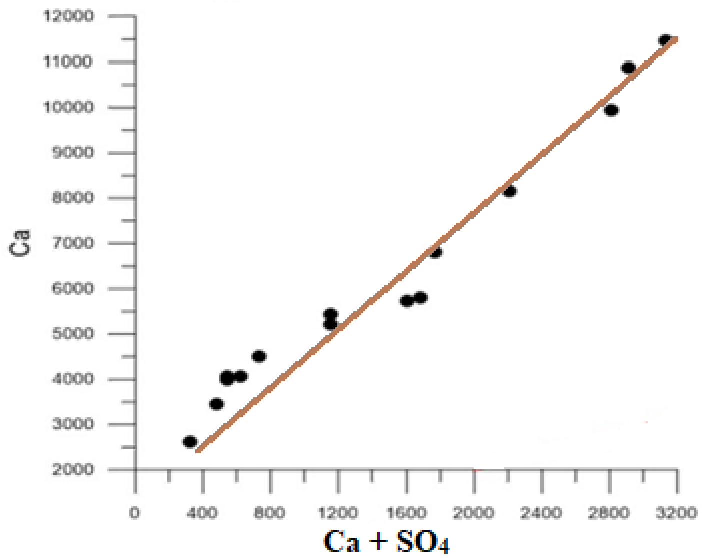

Figure 11: Ca^{+2} / Ca^{+2} $+SO_4^{-2}$) diagram for gypsum weathering type

5.6 Classifications and origin of Groundwater

5.6.1Pipper diagram

Further hydrochemistry of the area was revealed by the construction of Piper diagram1944, and Durov charts, though Durov's diagram Hawez et al, (2020) is more useful than Piper's diagram, because it also reveals hydro-chemical processes that affect the genesis of groundwater beside water Type. In general, groundwater is a type of fresh water dominated by bicarbonate ($HCO_3^- > SO_4^{2-} + Cl^-$).

Piper's graphic, however, shows that chloride and Sulfur water types are present, albeit at negligible concentrations. The Piper graph (Figures 12) shows that Mg-Ca HCO_3 dominates most groundwater samples, indicating that alkaline earth predominates over alkaline (therefore $Ca^{2+} + Mg^{2+} > Na^+ + K^+$). The remainder of the water samples are Na+K+HCO_3 water type, which likewise shows an abundance of alkalis above ground. Thus, none of the water samples fell into the ground wells. From Piper's plot, it is clear that the sample set was found in Mg and Ca for groups in the two seasons and are the main contributors to the water type that Mg-Ca-HCO_3 identified in the groundwater regime of the area. Where an individual drift closely to $Na^+ + K^+$ enrichment, it can be considered as the main contributor to the presence of Na + K+HCO_3 hydro-chemicals which are observed in Piper Three-line diagram **figure12**.

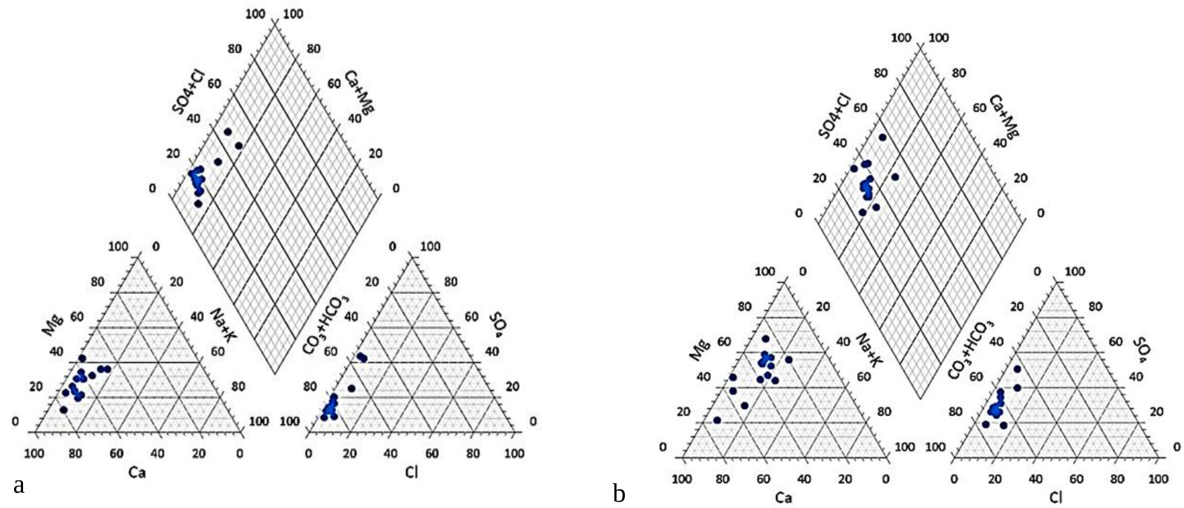

Figure12: Piper diagram of groundwater for seasonal variation;(a)wet season,(b)dry season

5.6.2.Durove diagram

Durov plot, which showed similar hydro-chemical aspects to Piper plot, where the cation field is a mixed type of water cation with the groups tended more to dominate the Mg-Ca ion while another group appears in $Na^+ + K^+$ ions (figure13).

Durov plot also refers to this simple degeneracy and reverse ion exchange are the two main hydro-chemical factors processes affecting the chemistry of groundwater in the study area. Most likely melting of calcite and dolomite are the main contributors to the dominance of Ca^{2+} -Mg^{2+} as shown by Cations in the groundwater system. Na^+ and K^+ spread, like Presented mostly by groups samples in April and October, helps to counteract atmospheric chloride deposition. This spread is caused by the disintegration of bytes and orthoclase.In Na^++K^+ spread, like Presented mainly by groups samples in the April and October seasons.

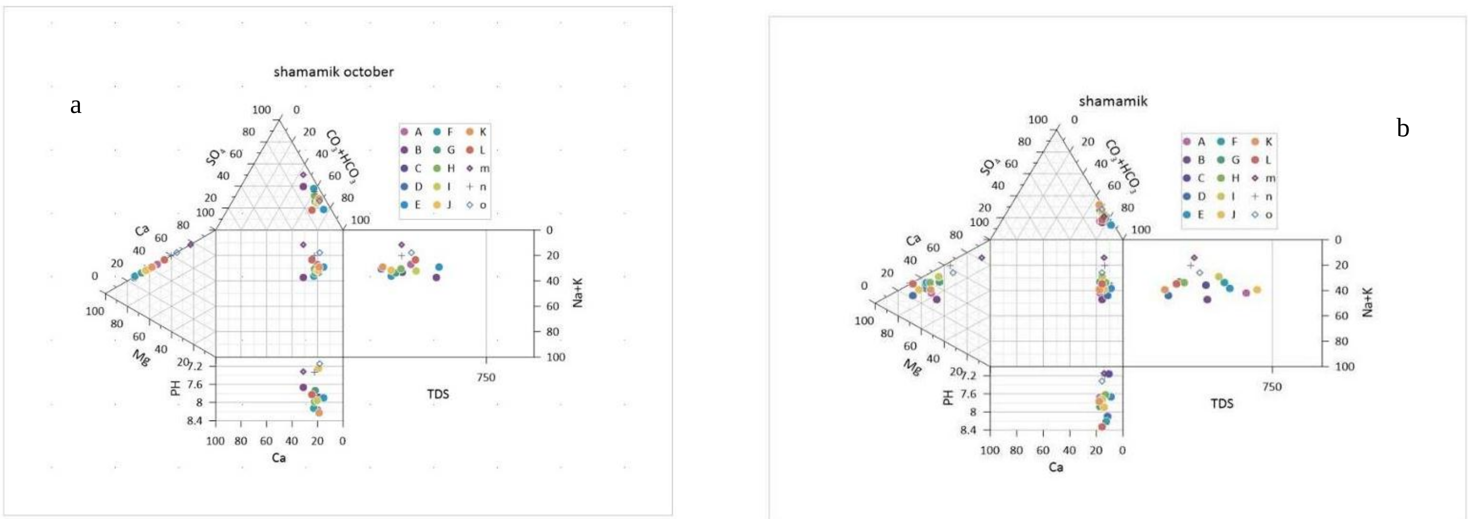

Figure13: Durove diagram of groundwater for seasonal variation

5.6.3 Scholler diagram

For a clearer representation of the primary hydrochemical features and potential controls for groundwater chemistry represented by these fifteen groups, the averages of the fifteen groups were utilized to draw a Schaller's diagram and rigorous schemas (Figures 13). A system with a relative average pH of 7.14 can be linked to the formation of carbonic acid from the reaction of carbon dioxide with precipitation or from the release of carbon dioxide from plant cells into the groundwater system. The majority of the samples that make up F-6 come from nearby geographic areas that are known for their rocks, including sandstone and limestone (Fatah et al., 2021).

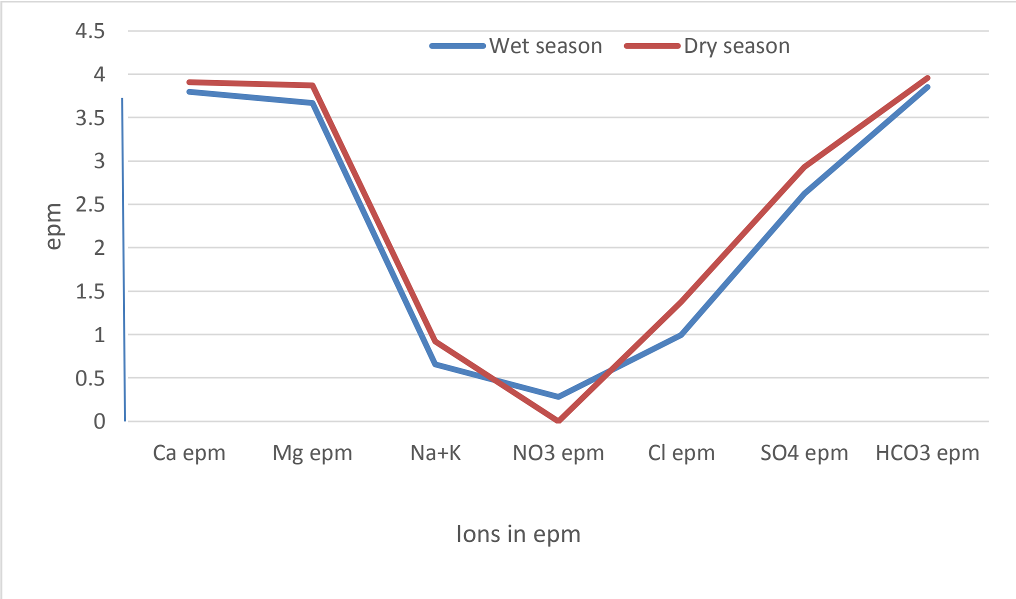

Figure14: Scholler diagram plotting for both seasons

According to this classification, parallel relationships in the hydro- chemical composition for the water reflects the effect of dissolution processes or weathering of rocks by the water, otherwise the water composition is from another source (Sjad &Ismael,2020).After application of Schoeller classification on groundwater water sample of wet and dry seasons, for wet season water type is F5, while in second season is F6 according to table2. The differences in (un parallel relationship) two season indicate the affections by pollution source(Perera,et,al.2022).

6.Conclusions

According to current study groundwater of Shamamik basin canbe use for drinking purpose based on physical parameters .Based on cation constituent are safe for drinking but based on an ion NO_3 and Cl wells 1,2,5,10, and15 are unsafe for drinking.The study found a deterioration of the quality of the studied water sources according to the EWQI values since it was of poor quality or very poor water when used for drinking because of the high concentrations of some ions such as calcium, which gives water unpleasant taste and sulfate ions give water a bitter taste and causing diarrhoea. The groundwater quality status in the area of study which was considered critical was that out of the 13 various parameters used in the assessment, about 12 of them were above the allowed levels that achieved WHO standards for drinking. The EWQ outcomes show that the groundwater studied was within a weak level which requires purification and treatment before utilizing it for domestic purposes. Additionally, the hydrogeochemical analysis of wells for dry and wet seasons revealed that all water samples have low turbidity values.

The findings show that using ground water for irrigation will not harm plants because all water samples had excellent SAR for all samples, whereas RSC, with the exception of sample 1 from Tandora village, all samples are good to medium. All samples are excellent, according to PI, with the exception of sample 15 (Girdmala village), which is unsuitable for irrigation.
Based on US salinity classification for irrigation 97% of the water samples presents medium

quality for irrigation and can be used for these purposes without posing any danger to soil or crops.

Origin of groundwater in studied are was Mg and Ca groups in both seasons and are the main contributors to the water type that Mg-Ca-HCO_3 according to Pipper1944. Mg-Ca type for both seasons based on Durove classification of groundwater type origin.

7.Recommendations

It is recommended that for periodic assessments of all physical, chemical, and biological water quality indicators guranteeing that there is no ongoing issues may develop within in the studied area. In order to better undertaidng and determining the origin, storage qualities, water dynamic, mixing rate, track the movement, and designate the recharge areas for the groundwater jaxtaposed to the studied areamuch carefull and attentsions must be paid while analyzing the groundwater samples and it is strogly recommned to use the high advanced analyses such as isotopic analysis.

8.Acknowledgments

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