HYDRO-CHEMICAL CHARACTERISTICS AND QUALITY ASSESSMENT OF SURFACE AND GROUND WATER QUALITY IN THE FIRST PART OF THE EASTERN SURMA-KUSHIYARA FLOODPLAIN BASIN FOR DRINKING AND IRRIGATION UTILITIES

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ABSTRACT

This study has been conducted in the first part of the Eastern Surma-Kushiyara Floodplain Basin located in Golapganj Upazila, Sylhet district, Bangladesh. A total of 60 water samples (30 for surface and 30 for ground) were gathered to examine the hydro-chemical properties of surface and groundwater. To define the water quality for general, drinking, and irrigation uses, several different statistical and graphical techniques were used. In addition, water quality parameters were utilized to assess the quality of the water for agricultural usage. A comparison of standard values for different parameters indicates that the condition of the water at the study site is not completely normal for drinking. According to the results, electro-neutrality balances are not properly satisfied. The most common water type in the field of study is Ca-HCO$_3$ water (both surface and ground), but Mg-HCO$_3$ water (33 percent of surface water samples) is also present. The obtained results also indicate that both the quality of surface and groundwater in the study site is suitable for the use of irrigation purposes. The outcome of this study is expected to be useful for the inspection of groundwater and surface water and for future regulations at the site of the study.

Keywords: Groundwater, Hydro-chemical Analysis, ICP-OES, Irrigation, Surface water

INTRODUCTION

Water is one of the most valuable natural resources because it can be redirected, distributed, preserved, and reused, making it one of the most versatile (Kumari, 2009). People's lives and livelihoods are dependent on water, which is important both in terms of consumption and in terms of the economy (Tiri et al., 2018). It is one of the most vital resources for humans and other living species (Hasan et al., 2020). It is a valuable component with diverse benefits in agriculture, industry, and everyday life (Zhang et al., 2018).

Groundwater is the principal source of freshwater needed for life on earth (Ayuba et al., 2013). According to estimates made by Nickson et al., (2005), around one-third of the world's population consumes groundwater for drinking. As a heterogeneous chemical mix, groundwater's composition is mostly influenced by how easily it dissolves in and interacts chemically with the rock or soil masses it travels through. The main cause of the change in groundwater chemical characteristics is hydrogeochemical reactions. But at the moment, groundwater provides 50% of urban water needs, 85% of rural drinking water needs, and 62.4 percent of net irrigation needs (Raju & Reddy, 1998).

Surface water quality is a crucial aspect (Simeonov et al., 2003). Surface water is used for many human purposes because it is easier to get than groundwater. It is used to irrigate agriculture and is a significant supply of drinking water. According to the National Geographic Society, nearly 80% of the water consumed in the United States in 2015 originated from surface water. Aquatic plants and animals have an important home in wetlands with surface water. Surface waters are prone to contamination due to the significance of containing industrial, municipal, and farming runoff across the watersheds (Singh et al., 2004). On the other hand, groundwater quality is deteriorating as a result of human activities. That is a major environmental problem (Brehme et al., 2011). Increased amounts of trace elements in drinking water, which is carried on by activities including sediment transport, industrial effluent, and mineral extraction, are becoming a severe health hazard nowadays (Tarun et al., 2022). The quality of regional groundwater supplies is highly dependent upon anthropogenic sources (Kallioras et al., 2006). Scientific understanding of water's hydro-geochemistry is essential for assessing water for drinking, agriculture, and a variety of other purposes (Sakram & Adimalla, 2018). Physical, chemical, and biological procedures are necessary for long-term monitoring and reporting, which have a positive influence on the water evaluation process, and expose contaminants (Liao et al., 2011).

This research is, therefore, being conducted in the Eastern Surma-Kushiyara Floodplain Basin, which is located in the Surma-Kushiyara (rivers) floodplain's considerably higher areas. River sediment from the northern and eastern hills emptied into the Meghna catchment region, forming the floodplain. The most prevalent source of drinking water in this area is groundwater. In addition, surface water is used in housework. Throughout the region, many agricultural activities are carried out all year round, and surface and groundwater are regularly used for these purposes. As a result, assessing the water quality in that location is essential for supplying the inhabitants with secure drinking water and proper farming. The study's major goal is to look at the chemical properties of the surface and groundwater in the first part of the Eastern Surma-Kushiyara floodplain basin. The objectives of this study are a) to determine the quality of surface and groundwater for household and agricultural usage in the anticipated region; and b) to compare the existing status of water quality properties to WHO and BS drinking water recommendations.

METHODOLOGY

2.1 Study Area:

This study has been performed on the first part of the Eastern Surma-Kushiyara Floodplain Basin. The research area covers around 250 square kilometers and is located between 24°41'N and 24°55'N and 91°55'E and 92°06'E. It is located around 10 kilometers east of Sylhet city. This area lies in the Golapganj Upazila, which is bounded on the north by the Surma River and the Kushiyara River on the south (see Figure 1, indicated in golden hue). This region was chosen because the water quality of the Surma and Kushiyara rivers has an impact on it.
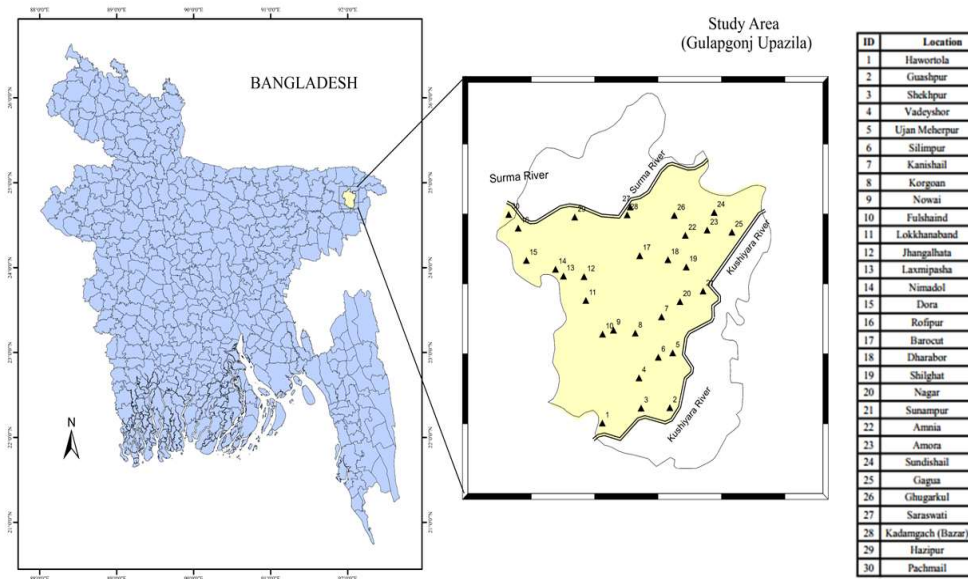
Figure 1: The colored area shows where the water was collected

2.2 Sample Collection:

All the water samples were collected from different stations in Golapganj Upazila. A total of 30 samples of surface water were taken from ponds and canals. The groundwater samples (30 samples) were taken from tube wells that are adjacent to selected ponds or canals. These groundwater samples were carried out after pumping for 5 minutes. The samples were stored in good-quality screw-capped, High-Density Polyethylene (HDPE) bottles, which were cleaned by acid and had a capacity of 1 liter. The bottles were rinsed three times before use. Ponds, rivers, and canals were used to collect surface water samples at 30 stations numbered SW-1 to SW-30. Furthermore, the groundwater samples were numbered GW-1 to GW-30. Two sets of samples were collected at each location. One of these two sample sets was used for cation analysis, and the other one was for anion analysis. In particular, samples had to be acidified with nitric acid (HNO_3) for cation analysis. After the collection of samples, the temperature, pH, electrical conductivity (EC), and total dissolved solids (TDS) of the samples were determined on-site using the HI9813-6 portable kit. Ice chests were used for the storage of all the samples as the permissible temperature was less than 4 °C. Subsequently, the samples were transferred into the laboratory for cation and anion analysis. All of the samples were kept in the refrigerator at temperatures below 4 °C. The analysis of anions (HCO_3^-, CO_3^{2-}, SO_4^{2-}, PO_4^{3-}, Cl^-, NO_3^-, F^-) was done by some representative methods. The HCO_3^-, CO_3^{2-}, and Cl^- anions were determined using the titration method. In addition, the DR6000 UV-VIS Laboratory Spectrophotometer was used to determine the rest of the anions (SO_4^{2-}, PO_4^{3-}, NO_3^-, F^-). The Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) technique was used to identify major cations (Na^+, Ca^{2+}, Mg^{2+}, K^+, Fe^{2+}, Si^{4+}, Rb^+, Al^{3+}, Mn^{2+}, P^{3+}). An instrument named the PerkinElmer Avio-200 was used for this technique. All these tasks took place in the laboratory.

2.3 Analysis:

The characteristics of a data collection are summarized or described using descriptive statistics. In this study, descriptive statistics such as average, standard deviation (SD), minimum, and maximum values were calculated for each parameter to study variability. Each sample was evaluated for reliability following analysis using this procedure to get the proportion of charge balance errors (%CBE) for each sample.

$$\%CBE = \frac{(\sum cations - \sum anions)}{(\sum cations + \sum anions)} \times 100\% \qquad (1)$$

meq/L is used to refer to both cations and anions in this context. A physicochemical analysis is frequently regarded as satisfactory if the CBE percentage is within ±5%. %CBE within ±10% indicates that all of the samples are in good condition. This study includes several graphical methods such as Collin's Bar Diagram, Stiff Diagram, Piper Diagrams (Trilinear), Durov Diagrams, Schoeller Diagrams, Wilcox Diagram, and US Salinity Laboratory (USSL) Diagram which provide an impactful assessment of the water samples. Some parameters are also used for this analysis. These are Magnesium Hazard (MH), Corrosivity Ratio (CR), Kelly's Ratio (KR), Sodium Absorption Ratio (SAR), Residual Sodium Carbonate (RSC), Permeability Index (PI), Soluble Sodium Percentage (Na%), Chloro-Alkaline Indices, and Scatter plots.

3 Results

3.1 Descriptive Statistics:

Table 1: Descriptive Statistics and Comparison of Surface and Groundwater Parameters with Standards.

Parameters	Surface				Guideline		Ground			
	Min.	Max.	Mean	SD	BS (mg/L)	WHO (mg/L)	Min	Max.	Mean	SD
pH	5.70	8.40	7.00	0.66	-	6.5-8.5	4.10	7.60	5.97	0.96
EC	0.04	0.29	0.13	0.08	-	-	0.01	0.54	0.17	0.14
TDS	33.00	209.00	103.47	55.60	1000	-	22.00	389.00	133.37	97.01
SO_4^{2-}	0.00	79.00	7.50	19.49	400	-	0.00	101.00	17.00	30.67
Cl^-	6.30	87.00	30.24	20.10	150-600	-	5.00	142.00	39.86	34.13
NO_3^-	0.10	2.10	0.81	0.59	10	50.0 as N	0.00	4.20	1.01	0.91
PO_4^{3-}	0.00	0.73	0.09	0.15	6	-	0.02	3.57	1.13	1.35
F^-	0.03	0.34	0.16	0.06	1	1.5	0.00	0.76	.216	0.13
CO_3^{2-}	0.00	0.00	0.00	0.00	-	-	0.00	0.00	0.00	0.00
HCO_3^-	20.00	190.00	71.20	48.63	-	-	10.00	330.00	103.03	82.95
Al^{3+}	0.00	0.65	0.07	0.14	0.2	-	0.00	2.20	0.34	0.57
Ca^{2+}	0.00	34.24	4.00	6.41	75	-	0.26	36.40	9.84	10.79
Fe^{2+}	0.00	14.05	1.88	3.39	0.3-1.0	-	0.00	4.79	0.57	0.94
Mg^{2+}	0.18	4.64	1.73	1.34	30-35	-	0.07	16.29	2.45	3.06
Mn^{2+}	0.00	0.54	0.14	.155	0.1	-	0.00	0.29	.075	0.08
P^{3+}	0.00	3.68	0.38	0.74	0	-	0.03	0.24	0.10	0.04
K^+	0.00	31.04	2.25	5.50	12	-	0.00	23.81	3.38	4.58
Na^+	0.00	55.05	7.38	11.04	200	-	0.00	23.27	5.91	7.01
Rb^+	0.04	1.42	.673	0.53	-	-	0.04	1.44	0.74	0.59
Si^{4+}	0.73	28.22	10.10	6.59	-	-	0.90	30.22	13.23	8.50

All values are in mg/L, except pH, EC (mS/cm), SD (Standard Deviation), BS (Bangladesh Standards)

Descriptive statistics are very useful for summarizing the basic information of a collected data set and for presenting various features of the entire scenario or a subset of it. Therefore, selected parameters of surface water and groundwater that were collected have been consistently summarized in Table 1 with their descriptive statistics. Na^+, Ca^{2+}, and Si^{4+} are the main dominating cations for both surface water and groundwater, while HCO_3^- and Cl^- are the leading dominating anions. Total dissolved solids (TDS) and HCO_3^- have the highest standard deviations, whereas Fe^{2+}, Al^{3+}, Mn^{2+}, P^{3+}, and Rb^+ have the lowest standard deviations in both surface water and groundwater. HCO_3^-, $SO4^{2-}$, Ca^{2+}, and Si^{4+} concentrations in groundwater were significantly higher than those in surface water, whereas Fe^{2+} and Na^+ concentrations were lower. Although groundwater's PH was lower than that of surface water, its total dissolved solids (TDS) concentration was much higher than that of the latter. This table also shows a comparison with the standard level for each parameter proposed by the World Health Organization

(WHO) and the Bangladeshi standard (BS) recommended by the Department of Public Health Engineering-DPHE (2021). The majority of the parameters are within the recommended limits. However, for both surface and groundwater, some water samples have pH values that are below the level recommended by the WHO. Besides, according to the BS, the Cl^- (chlorine) level should be between 150 and 600, and Mg^{2+} should be between 30 and 35. But, all of the water samples are below the requirements. Lastly, many water samples exceed the standard limits for Al^{3+}, Fe^{2+}, Mn^{2+}, P^{3+}, and K^+. Thus, both the surface and groundwater of the study area are not perfectly suitable for drinking purposes.

3.2 Graphical Analysis

3.2.1 Collin's bar diagram

It is a type of bar chart with vertical bars. On the left, major cations (Na^+, Ca^{2+}, Mg^{2+}, K^+, Fe^{2+}, Si^{4+}, Rb^+, Al^{3+}, Mn^{2+}, P^{3+}) in meq/L are plotted, while on the right, major anions (HCO_3^-, CO_3^{2-}, SO_4^{2-}, PO_4^{3-}, Cl^-, NO_3^-, F^-) in meq/L are plotted. The sum of cations and anions is 100 %. The results from the bar charts in terms of balancing of charges have found that out of 30 surface water samples, four are the best (the cation/anion imbalance is less than 5%), fifteen are better (between 5% to 10%), and the rest eleven are good (around 10%, but more than that) in variations. With 30 groundwater samples, similar results indicated that four of them are the best, sixteen are better, and the remaining ten are good in variations. The bar charts also indicated that the dominating ions among the anions and cations in both surface and groundwater are Si^{4+}, Na^+, Cl^-, HCO_3^-, and Ca^{2+}, respectively. A variation between the height of the cations and anions bars might be due to an analytical error or the absence of some ions that appear in large quantities.

3.2.2 Stiff Diagrams:

The corresponding concentration of the cations is plotted to the left of the center axis, while the equivalent concentration of the anions is plotted to the right. Each diagram is formed by connecting the points. All units are in meq/L. It is essential to produce each diagram using the same ionic species, in the same sequence, and on the same scale when comparing Stiff diagrams across various water samples. The concentrations of the major ions that were applied to identify the various groundwater and surface water samples in this study are shown in Figure 2.
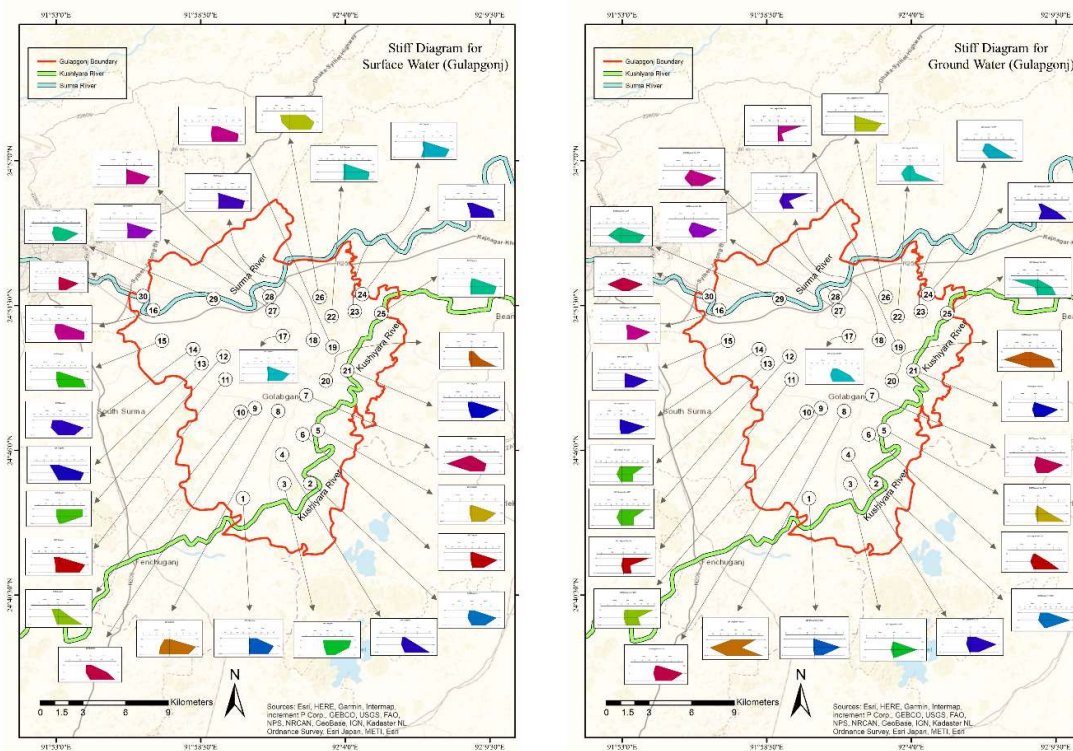
Figure 2: Stiff Diagrams of Surface Water Samples (Left Side) and Ground Water Samples (Right Side)

According to the stiff diagrams of surface water samples, the Ca cation is the most frequent among the cations, while the HCO_3 anion is the dominant anion in some locations. From Ground Water samples, 23% are Cl dominated and 20% of the samples are SO_4 dominated. From surface water samples, 26% of the samples are Mg-dominated. On the other hand, the Ca-HCO_3 water type is also the most commonly occurring water type for groundwater samples.

3.2.3 Piper diagram:

The Piper diagram for the surface, as presented in Figure 3, shows that 33% of surface water samples are plotted in the CaCl region and most samples (37%) are plotted in the Ca-HCO_3 region. Furthermore, 23% of samples are plotted in the Ca-Na-HCO_3 region. The rest of the samples were from the NaCl and Ca-Mg-Cl regions.

Similarly, the Piper diagram for the ground, shows that most groundwater samples (57%) are plotted in the Ca-Cl region and 40% of samples are plotted in the Ca-HCO_3 region. The rest of the samples were from the Ca-Na-HCO_3 region.
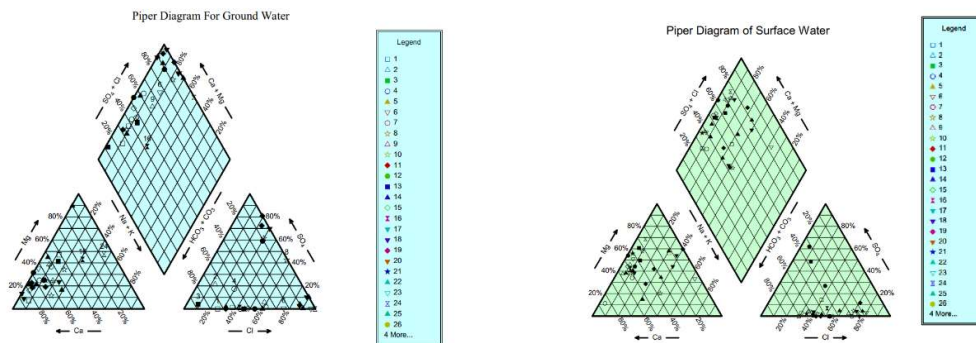

Figure 3: Piper Diagram for Ground Water (Left) and Surface Water (Right) Samples

3.2.4 Durov diagram:

A Durov diagram is a typical hydrogeology presentation tool that shows the major ions in two ternaries (trilinear) graphs with percentages of milli-equivalents. The data points are put into a grid pattern just at the base of every triangle. In addition, the cations and anions' values are plotted on two different triangular fixtures.
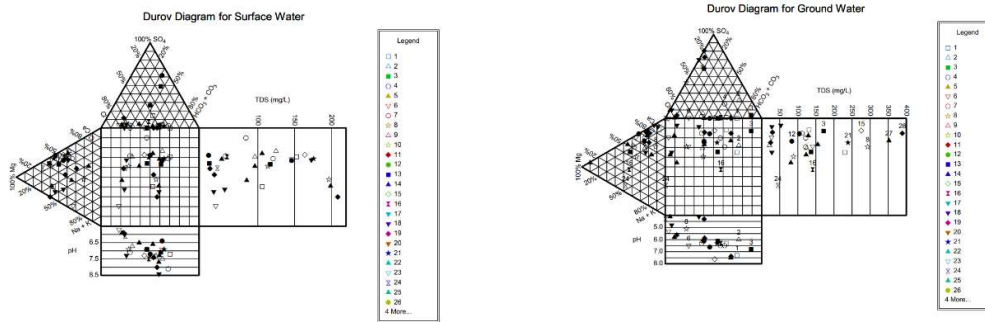

Figure 4: Durov Diagram for Surface Water (Left) and Groundwater(Right) Samples

According to Figure 4, Total Dissolved Solids (TDS) are below 100mg/L in nearly half of the surface water samples. All anions' concentrations are close to each other, showing a mixed sort of surface water. In the figure, the predominant ion concentrations of Ca and SO_4 for a significant percentage of Na and Mg are well-represented. On the other hand, total dissolved solids (TDS) is below 150mg/L in nearly half of the groundwater samples. All anions' concentrations are close to each other, showing a mixed sort of groundwater. Like surface water, the predominant ion concentrations for the groundwater samples are Ca and SO_4 for a significant percentage of Na and Mg.

3.2.5 Schoeller diagram:

Schoeller diagrams are used to illustrate relative anions and cations concentrations, which are commonly given in milli-equivalents per liter. The chemical features of water compositions were analyzed based on major ion concentrations. The Schoeller diagram is determined for each ground and surface water sample as explained below.

In Figure 5, all the samples are plotted on Schoeller semi-logarithmic diagrams for each groundwater sample. The diagram shows that the concentration of HCO_3^-, Cl^-, SO_4^{2-}, Mg^{2+}, Ca^{2+}, and K^+ are high and the concentration of CO_3^{2-}, and Na^+ are low.
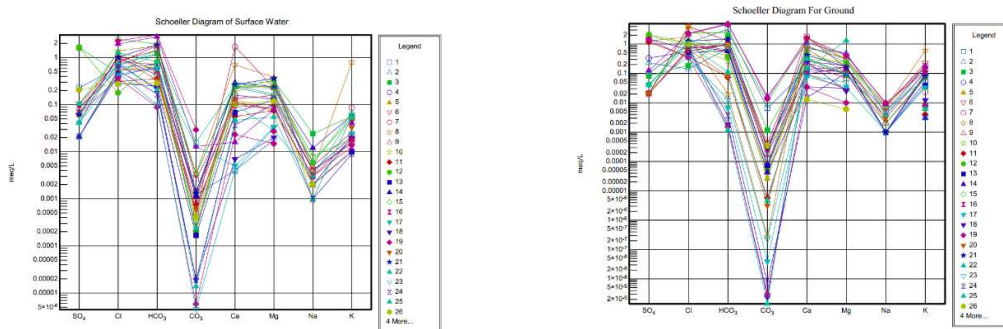

Figure 5: Schoeller Diagram for Surface Water (Left) and Ground Water (Right) Samples

3.2.5 US Salinity Laboratory (USSL) diagram:

Such a diagram is mostly used to define irrigation water investigation. In the vertical axis, it needs to employ the sodium absorption ratio (SAR), and in the horizontal axis, it employs conductance. Water is divided into 16 categories in this diagram. From the USSL diagrams in Figure 6, it can be said that

the majority of all water samples (surface and groundwater) have fallen into the C1-S1 class, which indicates that both salinity and sodium hazard are low.
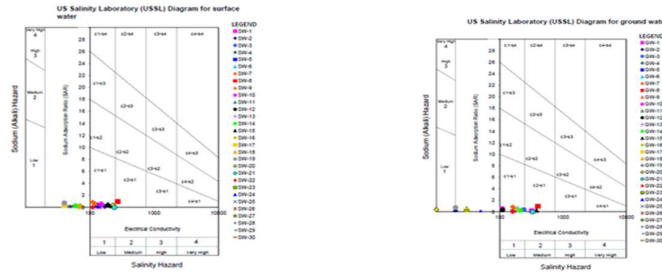

Figure 6: USSL diagram of Surface (Left) and Ground Water (Right) Samples

3.3 Parameters: Suitability for Irrigation Usage

Several water quality parameters that have been discussed are determined in Table 2 and Table 3 for the surface and groundwater samples, respectively.

Table 2: Water Quality Parameters for Surface Water Samples

Samples no	MH	PI	RSC	Kelly's Ratio	Corrosively Ratio (CR)	Chloro Alkaline Index-1	Chloro Alkaline Index-2	SAR	SSP
1	81.82	4073.19	0.78	0.00	2.80	0.98	0.59	0	31.67
2	39.49	291.62	0.92	0.01	1.67	0.97	0.48	0.012	4.8
3	56.70	205.66	0.88	0.04	3.26	0.83	0.13	0.063	12.3
4	44.83	243.79	0.22	0.01	5.71	0.98	1.89	0.016	8.16
5	41.44	556.22	0.85	0.01	1.60	0.98	0.51	0.011	6.98
6	54.30	464.66	1.58	0.01	1.41	0.98	0.42	0.014	6.23
7	11.82	49.87	0.00	0.00	2.50	0.89	0.77	0	4.26
8	35.14	129.96	0.91	0.00	2.04	0.42	0.28	0.007	42.38
9	49.13	188.97	0.31	0.01	4.30	0.97	1.33	0.015	6.28
10	64.24	150.82	0.10	0.00	6.10	0.96	1.64	0.003	9.85
11	57.58	474.32	0.26	0.00	2.26	0.85	0.64	0	26.97
12	49.80	260.37	1.15	0.01	2.40	0.67	0.04	0.016	10.73
13	64.62	291.73	0.13	0.01	2.46	0.96	0.80	0.008	5.63
14	45.32	155.98	0.17	0.02	1.78	0.83	0.48	0.033	11.74
15	46.80	293.29	1.70	0.02	3.19	0.99	1.10	0.022	5.13
16	46.37	417.93	0.40	0.02	3.11	0.97	0.82	0.012	7.98
17	87.18	2023.86	0.58	0.00	2.08	0.94	0.60	0.002	37.94
18	74.07	3249.99	0.74	0.00	2.62	0.97	0.89	0	40.33
19	39.47	1615.80	0.34	0.00	3.12	0.96	0.80	0	27.21
20	44.39	286.92	0.16	0.00	8.04	0.97	2.22	0.001	13.48
21	57.59	247.60	1.83	0.00	1.23	0.98	0.39	0.005	3.3
22	53.92	423.05	0.72	0.01	2.86	0.93	0.85	0.004	35.77
23	88.89	2104.52	0.54	0.00	2.47	0.87	0.69	0.004	62.52
24	73.57	498.18	0.35	0.01	3.20	0.98	1.01	0.004	6.43
25	21.54	905.14	1.31	0.02	2.72	0.95	0.79	0.016	31.56
26	54.26	255.43	0.11	0.01	3.78	0.99	0.49	0.009	0.97
27	83.16	1797.81	2.82	0.00	1.91	0.98	0.65	0	29.89
28	100.00	6535.75	3.09	0.00	2.10	0.99	0.72	0	39.35
29	39.53	283.18	1.05	0.01	1.34	0.89	0.37	0.018	13.99
30	42.19	744.33	1.91	0.02	1.04	0.97	0.35	0.014	10.15

Table 3: Water quality parameters for groundwater samples

Samples no	MH	PI	RSC	Kelly's ratio	Corrosively ratio (CR)	Chloro Alkaline Index-1	Chloro Alkaline Index-2	SAR	SSP
1	53.31	624.17	3.27	0.00	0.88	1.06	0.30	0.004	11.74
2	42.32	126.94	1.14	0.00	0.38	-0.64	0.01	0.008	8.39
3	22.03	403.48	2.14	0.00	0.28	0.14	0.07	0.001	2.07
4	41.46	301.22	1.31	0.00	1.32	0.47	0.24	0.003	10.88
5	23.17	320.24	1.41	0.00	6.08	3.88	2.08	0	7.3
6	27.85	132.94	1.08	0.01	5.23	3.95	1.69	0.014	17.5
7	26.82	492.90	1.39	0.00	1.22	0.67	0.41	0	8.22
8	15.08	31.10	0.00	0.00	20.18	1.36	0.64	0.01	23.68
9	29.91	414.37	1.46	0.01	1.75	0.94	0.50	0.008	18.43
10	43.99	155.10	0.20	0.01	8.82	0.76	0.29	0.021	22.1
11	23.58	441.58	0.17	0.00	11.79	0.36	0.25	0	3.17
12	28.05	151.46	0.38	0.00	6.99	0.99	0.31	0.003	11.29
13	48.15	545.02	1.51	0.00	0.83	0.43	0.26	0.001	13.85
14	46.97	2294.84	2.23	0.00	1.05	0.84	0.37	0	3.74
15	16.69	94.15	0.90	0.00	2.60	2.33	0.86	0.003	4.7
16	63.04	560.37	1.86	0.01	0.97	0.54	0.27	0.011	31.44
17	30.63	457.91	0.15	0.01	4.33	0.28	1.06	0.004	23.19
18	9.12	209.02	0.05	0.00	15.18	0.63	0.35	0	4.11
19	22.73	964.24	0.14	0.00	21.73	0.31	0.21	0	16.38
20	13.42	94.49	0.00	0.00	3.40	0.64	1.09	0.006	0.35
21	28.47	302.66	2.60	0.00	1.13	1.20	0.37	0.004	12.67
22	23.21	110.31	0.00	0.01	13.50	0.75	2.10	0.012	29.12
23	35.77	295.60	0.03	0.00	5.90	0.33	1.78	0	2.13
24	87.39	554.86	0.32	0.01	4.74	0.60	1.37	0.006	45.66
25	90.30	58.51	0.00	0.00	3.75	0.95	1.17	0	0.44
26	31.58	6176.09	1.36	0.00	2.11	1.02	0.73	0	1.18
27	28.31	144.78	3.53	0.01	1.29	2.12	0.39	0.014	10.54
28	19.90	114.49	3.38	0.00	1.22	2.26	0.40	0.014	5.85
29	20.47	112.43	0.50	0.01	2.27	1.22	0.71	0.011	5.67
30	7.77	73.63	0.13	0.00	0.79	0.24	0.18	0.007	8.56

3.3.1 Magnesium Hazard (MH)

According to Table 2, the MH value of 50% of surface water samples is less than 50. Meanwhile, the remaining samples have an MH value greater than 50. Similarly, from Table 3, it is found that the majority of groundwater samples have an MH value of less than 50 (87%). Thus, according to Magnesium Hazard parameters, both the surface and groundwater of most of the study area are suitable for irrigation purposes.

3.3.2 Kelly's Ratio (KR)

According to Table 2 and Table 3, all the surface and groundwater samples have a KR value of less than 1. So, we can conclude from Kelly's Ratio parameters that both the surface and groundwater of the study area are suitable for irrigation.

3.3.3 Corrosivity Ratio (CR)

As there is no surface sample whose CR value is less than 1, surface water samples are not suitable for any pipe transmission (Table 2). In addition, groundwater samples are also unsatisfactory, though some samples (GW-1, GW-2, GW-3, GW-13, GW-16, and GW-30) are in the permissible range (Table 3).

3.3.4 Residual Sodium Carbonate (RSC)

The RSC values are calculated using the respective formulas for both surface and groundwater samples (Table 2 and Table 3). An RSC value of less than 1.25 is safe, while greater than 2.5 is unsuitable. If RSC is laid between 1.25 and 2.5, the water is marginally suitable. The majority (77%) of surface water samples indicate that they are safe for irrigation purposes, and fifty-seven percent of groundwater samples are in the safe category.

3.3.5 Sodium Absorption Ratio (SAR)

In our study region, the SAR concentration ranges are from 0.001 to 0.021 for surface water samples, while the SAR concentration ranges are from 0.001 to 0.063 for groundwater samples. Thus, according to the sodium absorption ratio, all the samples are suitable for irrigation purposes in the study area.

3.3.6 Soluble Sodium Percentage (SSP)

It can be shown that almost all of the surface water samples have SSP values of less than 50; only 1 surface water sample is unsuitable. However, all of the groundwater samples have SSP values of less than 50. As a result, all of the observed samples were found to be suitable for irrigation purposes in the study area.

3.3.7 Permeability Index (PI)

The analyzed samples' surface water permeability index is 49 percent and above, while the groundwater samples' permeability index is 31 percent and above. As a result, both surface and ground samples fall into Class-I and Class-II which are suitable for irrigation purposes in the study area.

3.3.8 Ion Exchange process

Although controlling the dissolution of harmful materials in subsurface water is challenging, it is essential to understand the changes that water undergoes during surface runoff and infiltration. The Chloro-alkaline indices (CAI) can be used to imply ion exchange between groundwater as well as its environment throughout residency with percolation.

The CAI-1 values, including all surface water samples, are positive, and the CAI-2 values are also positive, as shown in Table 2. As a result, the values can be described as direct base-exchange reactions. Furthermore, except for one sample of groundwater (CAI-1 value is negative for GW-3), all the other groundwater samples give positive values of CAI-1 and CAI-2 which indicate a direct base-exchange reaction (Table 3).

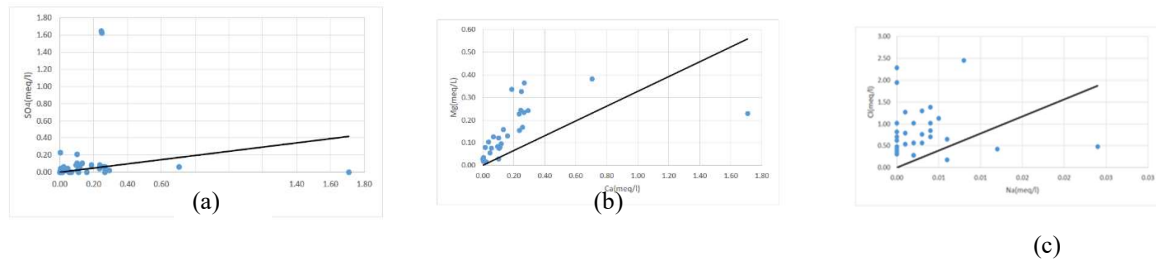### 3.4 Hydrochemical processes (Using Scatter plots)

Figure 7: Scatter plots showing relationships between (a) Ca vs SO₄ (b) Ca vs Mg (c) Na vs Cl (for surface water samples)
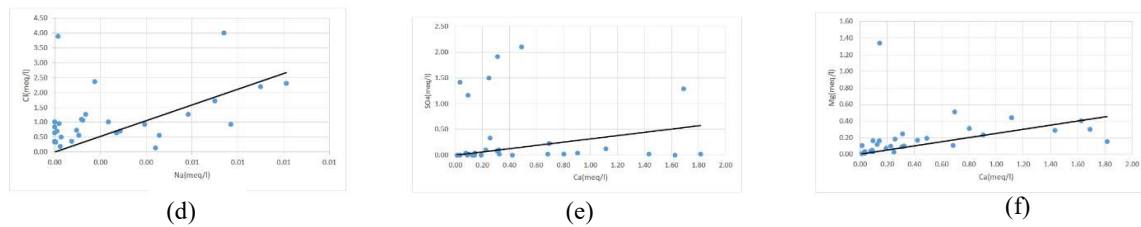

Figure 8: Scatter plots showing relationships between (a) Ca vs SO₄ (b) Ca vs Mg (c) Na vs Cl (for groundwater samples)

From the scatter plots in Figures 7 and 8, it can be seen that only Figure 7(b) shows the absence of a significant correlation between the cations. All points of the samples are plotted on the Ca^{2+} and SO_4^{2-} graph (Figure 7(a) and Figure 8(d)), indicating that Ca^{2+} and SO_4^{2-} are the only cause of gypsum breakdown. Most plots are above the straight line in Figure 7(c) and Figure 8(f), showing that Na^+ is not just derived from halite but also from other minerals or processes such as cation exchange.

4. CONCLUSIONS

In this study, several graphical diagrams and water quality parameters have been used to assess the surface and groundwater suitability. This study effectively used hydro-chemical assessment and statistical approaches to quantify water quality variation and identify probable anthropogenic origins of water quality trends at sampling locations. From Collin's bar diagrams of water samples, it was observed that the region of this study is Si^{4+}, Na^+, Cl^-, HCO_3^-, and Ca dominated as their concentrations were found to be very high. Surface and groundwater were classified based on constituent ionic concentrations using Piper's trilinear diagram approach. Most of the soil can be irrigated through ground and surface water, according to the Wilcox diagram and the US salinity diagram. In addition, Sodium Adsorption Ratio (SAR), Soluble Sodium Percentage (SSP), Magnesium Hazard (MH), Residual Sodium Carbonate (RSC), Permeability Index (PI), and Kelly's ratio (KR) values suggested that the samples (both surface and ground) could be suitable for irrigation. These values are in the permissible range for which the suitability for irrigation uses has been stated theoretically. The Corrosivity Ratio (CR) showed that both surface and groundwater are not suitable for transmission through pipes as the values exceed the acceptable range. Scientific fertilization techniques should be used in the study area, and the total amount of fertilization should be strictly regulated. Due to the serious health hazards in this region, new centralized water supply sources must be constructed to provide communities with purified groundwater. Monitoring the quality of Groundwater and preserving the sources of water supplies should be improved during this time. The research will make it easier to establish a safe drinking water system and an adequate irrigation system.

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