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Assessment of Groundwater Quality in Rutba Area, Al-Anbar, Western Iraq

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Abstract

The Rutba area is located within the arid region in the western desert of Iraq. Although no surface water is available in this area, the groundwater is considered the water source in the area. The aim of research is to investigate groundwater type and quality in the Rutba area using multivariate statistics approach. To evaluate the groundwater, fifteen groundwater samples were collected in the study region during the period of September 2019 and analyzed for essential anions and cations. The groundwater samples are considered to be fresh. Groundwater within the study region is dominated by calcium and sulphate ions refers to carbonate rock from the Mulussa Formation. The type of groundwater sample of the study region is earth alkaline water dominated by sulphate and chlorine and normal earth alkaline water with prevailing sulphate or chlorine except well no 3 which has been classified as alkalin water dominated by sulphate and chlorine. The correlation coefficient analyses of the groundwater samples show a strong correlation between Ca- Cl and Mg-Cl. The cluster Analysis is divided into four cluster of similar characteristics related to water quality. Principle components analysis shows high positive correlation between groundwater parameters and Factor 1. The Factor 1 reflects the role of the geogenic process like the dissolution of carbonate and dolomitic rocks prevalent in the study area.

Keywords: Groundwater quality; Multivariate statistical; Piper diagram; Rutba

1. Introduction

Water's impact on health is primarily due to the consumption of water containing toxic chemicals or pathogenic organisms (Awadh et al., 2016). In recent years, it has become exceedingly difficult, to meet increased demand while also providing adequate quality water to the population as a result of pollution (Awadh. 2018; Nnorom, et al., 2019; Awadh et al., 2021). Rutba area is based on groundwater in possessing different economic activities including agriculture and livestock uses. Groundwater is considered as the only secure supply of water in the region. The study region located in Al-Anbar, Western Desert of Iraq. It bordered by longitudes of 40˚7′10″- 40˚38′00″ and latitudes of 32˚54′00″ – 33˚11′00″. The total area is expanded by about 1548 Km^2 (Fig.1). Tectonically, the study region is located within the stable shelf in the Rutba-Jezira Zone, which is located within Rutba-Jezira Zone that is characterized by containing large basement high, no surface anticlines, dominated by the Huge Rutba Uplift (Jassim and Buday, 2006). Geologically, the study area includes many geological formations (from older to younger) (Fig. 2): Gaara Formation (Early Late Permian), Mulussa Formation (Late

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Triassic, Carnian-Norian), Zor Hauran Formation (Late Triassic, Rhaetic), Ubaid Formation (Early Jurassic, Lias), Mauddud-Nahr Umr Formations (Early Cretaceous, Albian-Cenomanian), Rutba Formation (Late Cretaceous, Cenomanian), Ms`ad Formation (Late Cretaceous, Cenomanian - Turonian), Hartha Formation (Late Campanian-Early, Maestrichtian) and Quaternary deposits: Include depression and fill valleys sediments, as well as the calcareous soils and occupy various areas within depressions and slopes (Al-Kubaisi and Al-Kubaisi, 2018). In the study area, the groundwater exists in Mulussa Aquifer (dolomite and limestone) beds, which represent the saturation zone, While the zone of unsaturation includes Mauddud, Ubaid, Zor Hauran formations in addition to Quaternary deposits (Fig. 3). The research proposed to re-evaluate groundwater in the Rutba area as well as study the multivariate analysis of he studied samples in the area.

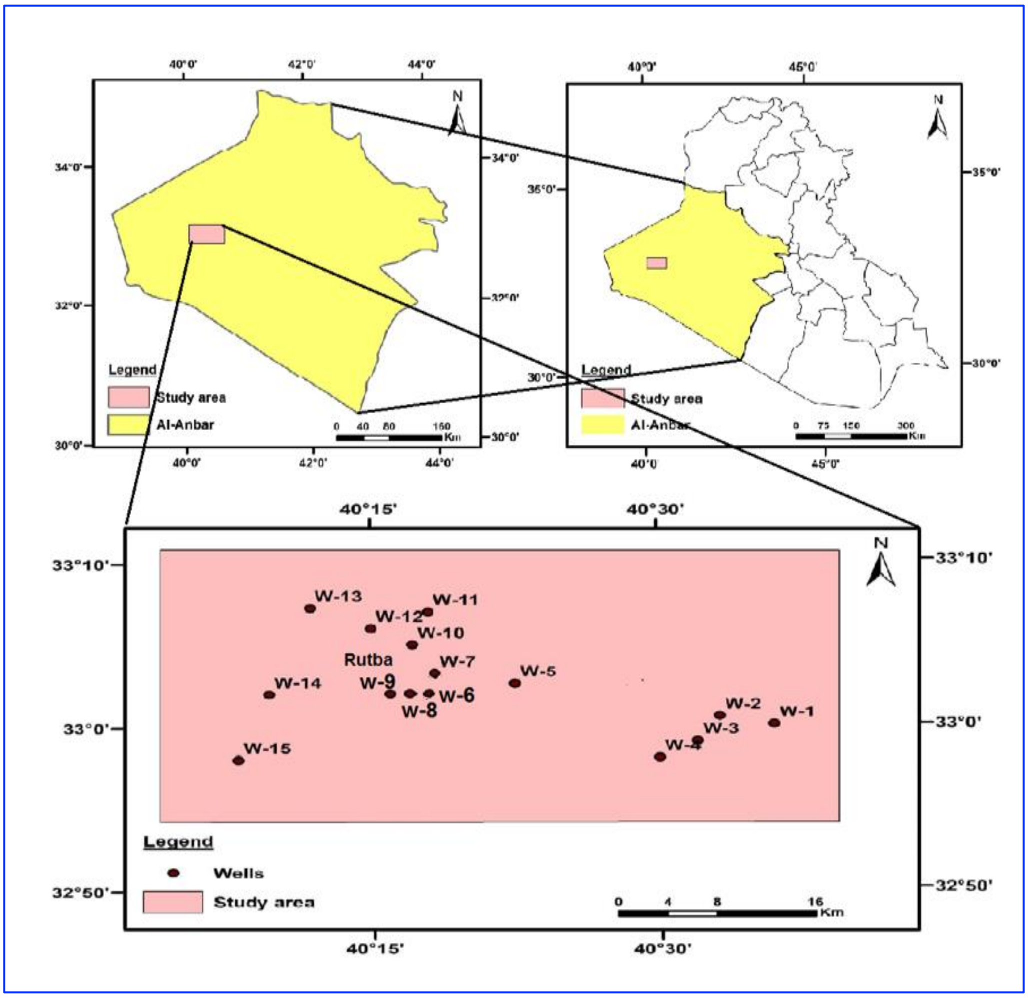

Fig. 1. Location of the study region and location of groundwater sampling sites

2. Materials and Methods

Fifteen groundwater samples were taken on September 2019 (Tables 1). A sample was collected from each well in bottles. All bottles were labeled with identification name, code number, coordinates and date of sampling. The measurements and analyzes of main ions were carried out in General Commission of Groundwater, Ministry of Water Resources. Each of these groundwater samples were analyzed for 11 parameters, these are TDS, pH, EC, sodium, potassium, calcium, sulfate, magnesium, bicarbonate, chloride and nitrate using a standard procedure of APHA, (2005).

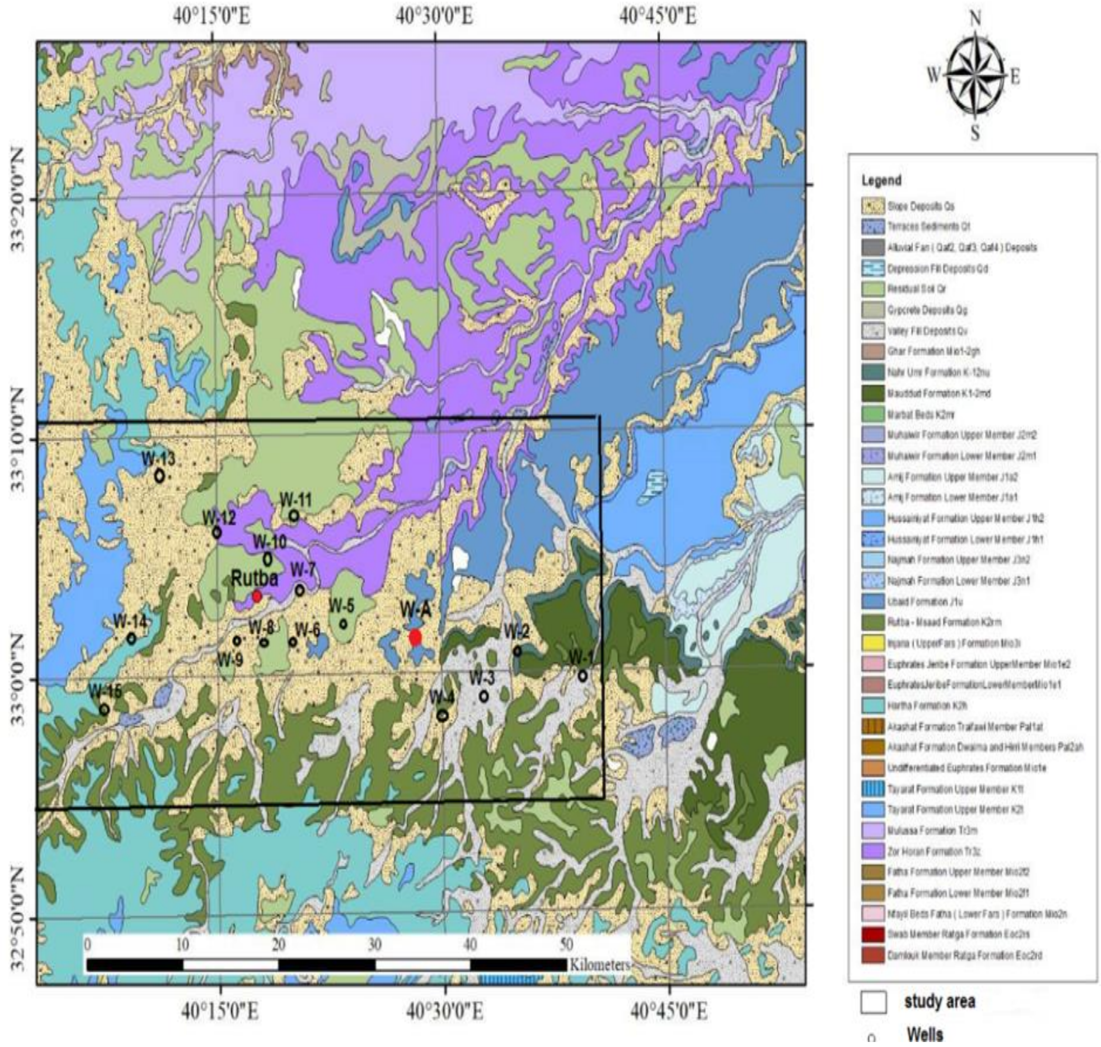

Fig. 2. Geologic map of the study area (GCG, 2021)

Table 1. Physical and chemical characteristics of groundwater sample in the study region in (ppm) units

Well	Longitude	Latitude	pH	EC	TDS	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Cl^{-}	HCO_3^{-}	SO_4^{-2}	NO_3^{-}
W-1	E 40˚36' 00"	N 33˚ 00' 00"	7	1210	748	120	46	69	0.0	160	229	238	13
W-2	E 40˚33' 10"	N 33˚ 00' 30"	8	1102	618	54	25	135	0.0	135	201	170	9
W-3	E 40˚32' 00"	N 32˚ 59' 00"	7.4	960	568	74	45	50	0.0	153	131	170	22
W-4	E 40˚30' 00"	N 32˚ 58' 00"	7.5	980	613	82	55	51	0.0	153	183	170	18
W-5	E 40˚22' 30"	N 33˚ 02' 35"	7.6	676	353	44	27	46	0.0	62	168	87	3
W-6	E 40˚18' 00"	N 33˚ 02' 00"	7.3	609	348	58	21	38	0.0	49	192	67	10
W-7	E 40˚18' 19"	N 33˚ 03' 15"	8	1785	998	136	76	101	0.0	399	156	208	18
W-8	E 40˚17' 00"	N 33˚ 02' 00"	8	1800	1181	120	45	201	0.0	189	270	320	8
W-9	E 40˚16' 00"	N 33˚ 02' 00"	8	3210	1908	224	82	354	0.0	650	22	365	11
W-10	E 40˚17' 10"	N 33˚ 05' 00"	7.7	1273	795	90	48	105	0.0	209	165	245	15
W-11	E 40˚18' 00"	N 33˚ 07' 00"	7.7	2105	1265	198	66	184	0.0	380	253	380	30
W-12	E 40˚15' 00"	N 33˚ 06' 00"	8	1000	650	23	22	200	0.0	182	78	235.2	12
W-13	E 40˚03' 30"	N 33˚ 08' 30"	8	960	574	62	29	110	0.0	124	189	144	5
W-14	E 40˚09' 39"	N 33˚ 02' 00"	8	980	715	68	50	115	0.0	192	183	187	7
W-15	E 40˚08' 00"	N 32˚ 58' 00"	8	1087	605	122	19	70	0.0	124	265	138	2

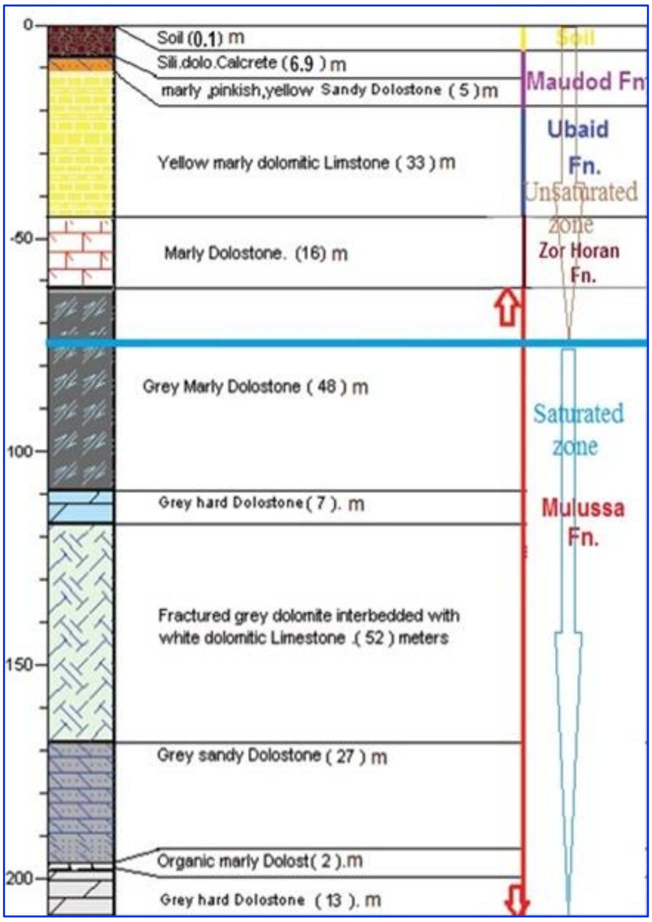

Fig. 3. The geological section of study area (W-A) (Al-Dulaymi et al., 2013)

3. Results and Discussion

3.1. Physical and Chemical Limitations

The suitable pH range is between 6.5 and 8.5 (WHO, 2007). The pH varies in groundwater samples between 7.3 – 8. The pH values of groundwater samples are of low alkalinity. Significant TDS variation in groundwater samples was detected. Groundwater samples are considered to be fresh to slight water based on the TDS values (348 - 1908 mg/l) according to Drever, (1997). The water ionic composition accurately described the source and chemical quality of the various water kinds. calcium > sodium> magnesium > potassium and sulfate > bicarbonate > chloride in the water samples is sorted in decreasing abundance of cations and anions. The concentration of NO_3 groundwater sample range between (2 - 30). The increase in some well is due to agricultural activities.

3.2. Hydro-Chemical Classification

The trilinear diagram (Piper,1944) was used to classify the groundwater samples depending on their main anion and cation. The hydro-chemical facies of groundwater samples in the study region are revealed in Fig. 4, where most groundwater samples are located in class (e and c). This means the type of groundwater samples of the study region are earth alkaline water dominated by sulphate and chlorine and Normal earth alkaline water dominated by sulphate or chlorine except for well no 3 have been classified Alkaline water with dominant sulphate and chlorine.

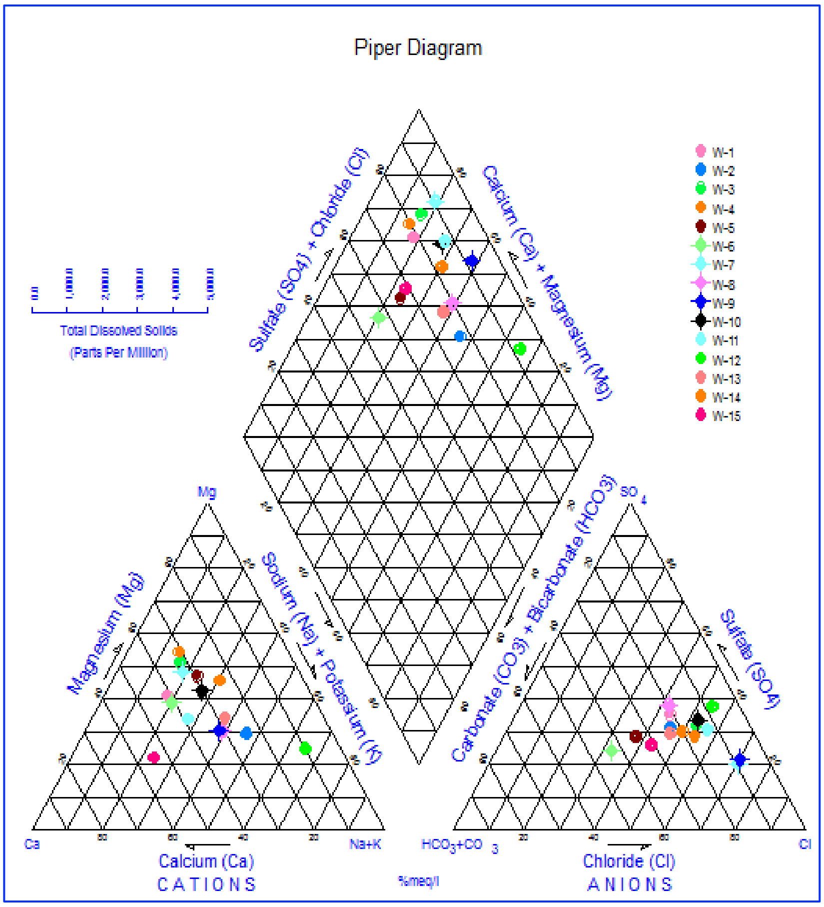

Fig.4. Type of groundwater according to Piper, (1944).

3.3. Statistical Analysis

Multivariate analysis is an important statistical technique used for analyzing and interpreting randomly distributed data sets. For the purpose of the present study the groundwater samples were evaluated Correlation Matrix Analysis. The variables used in this study are pH, TDS, EC, NO_3^-, Cations and Anions for 15 groundwater samples.

3.3.1. Correlation matrix analysis

A correlation matrix analysis was used to identify the 8 elements' interrelationships (Table 2). Wang's (2018) classification method was employed. When $r > 0.8$ as of high relevance; $0.8 < r < 0.5$ as median relevance; $0.5 < r < 0.3$ as 'less relevance'; and $r < 0.3$ was considered of no relevance (Wang, 2018). In general, high correlations (p 0.01) were observed, with correlation coefficients ranging from 0.835 to 0.990 for the pairs Ca- Cl and Mg-Cl, which were found to be of high relevance. Mg-Ca; Na-Ca; Na-Cl; Ca-SO4; Mg-SO4; Na-SO4; SO4-Cl and Mg-NO3 showed median relevance in correlation coefficients ranging from 0.577 to 0.796, while Mg-Na; Ca-NO3; NO3-Cl and SO4-NO3 showed less relevance in correlation coefficients ranging from 0.386 to 0.493. The correlation with the elements of TDS revealed that high positive correlation between TDS and Na, Ca, Cl, and SO4, ranging from 0.873 to 0.933, while the pairs of Mg- TDS correlated significantly, with a median relevance of 0.785 (Table 2).

Table 2. Correlation Matrix Analysis of groundwater samples, Pearson Correlation

	pH	Ec	TDS	Ca^{+2}	Mg^{+2}	Na^{+}	K^{-}	Cl^{-}	HCO_3^{-}	SO_4^{-2}	NO_3^{-2}
Ec	.333	1									
TDS	.342	.990	1								
Ca^{+2}	.093	.897	.875	1							
Mg^{+2}	.066	.785	.787	.769	1						
Na^{+}	.54	.850	.873	.583	.475	1					
Cl^{-}	.335	.950	.933	.835	.855	.792	b	1			
HCO_3^{-}	-.151	-.311	-.294	-.013	-.294	-.455	b	-.485	1		
SO_4^{-2}	.233	.850	.890	.754	.683	.796	b	.769	-.115	1	
NO_3^{-2}	-.308	.308	.303	.396	.577	.073	b	.386	-.058	.493	1

**. At the 0.01 level, correlation is significant (1-tailed).

b. Because at least one of the variables is constant, the computation is impossible.

3.3.2 Cluster analysis

To further investigate element origins, all groundwater samples were used for cluster analysis using the average linkage method to classify variables depend on spatial similarities (between groups). In the Rutba area, the dendrogram of groundwater samples revealed two common clusters I and II. Cluster I contained TDS and EC. Cluster II contained of sub clusters 1,2 and 3. Sub cluster 1 includes SO_4^{-2}, Cl^- and HCO_3^- sub cluster 2 contained Ca^{2+} and Na^+, sub cluster 3 contains K^+, Mg^{2+}, No_3^- and pH. Grouping of cations (Mg^{2+}, Ca^{2+}, K^+ and Na^+) and anion (SO_4^{2-}, Cl^- and HCO_3^-) in one cluster reflect strong correlations between them, implying a common source (Fig. 5).

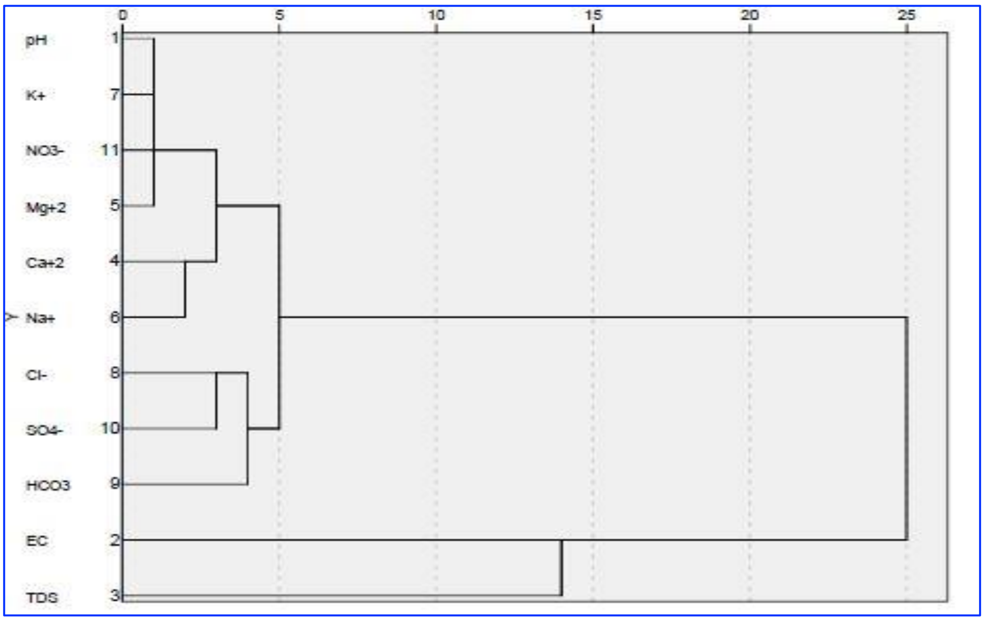

Fig. 5. The cluster analysis (CA) of groundwater parameters in the Rutba region is represented as a dendrogram

3.3.3. Principle components analysis

To determine similarities and differences between sampling sites, the principal component analysis suggested possible sources of water pollutants and their associated research parameters (Hernández-Mena, 2021). The data set of ten groundwater parameters in the Rutba region was subjected to principle components analysis, and factor loadings were calculated (Tables 3). The varimax rotated factor matrix, the percentage of variance, the eigenvalues, and the cumulative percent of the rotated are all shown in the table. In the Rutba region, factor 1 explains 62.579 % of the total variation and has high positive loadings on TDS, EC, Ca^2, Mg^{2+}, Na^+, SO_4^{2-} and Cl^-. These strong positive loadings show a high positive between groundwater parameters and factor 1. The factor 1 reflect the role of geologic processes like the dissolution of carbonate and dolomitic rocks prevalent in the study area. Factor 2 explains 16.386 % of the total variance as well as strong positive loading in NO_3^-. Factor 3 explains 10.117 % of total variation and has a high negative load on HCO_3^-.

Table 3. Factor loadings of groundwater parameters in the Rutba area

Variable	Factor 1	Factor 2	Factor 3
Ph	.326	-.778	.232
EC	.982	-.057	.078
TDS	.984	-.066	.099
Ca^{2+}	.869	.245	.269
Mg^{2+}	.841	.323	-.142
Na^+	.846	-.428	-.002
Cl^-	.969	-.041	-.145
HCO_3^-	-.358	.338	.866
SO_4^{2-}	.891	.111	.195
NO_3^-	.423	.742	-.202
Eigenvalue	6.258	1.639	1.012
% Total variance	62.579	16.386	10.117
% Cumulative	62.579	78.965	89.082

4. Conclusions

The groundwater samples are considered to be fresh to slightly water based on the TDS value. Groundwater within the study region is dominated by calcium ions and sulphate ion refers to carbonate rock from the Mulussa Formation. The type of water sample in the study area is classified in class e and class c according to the Piper diagram, the types of groundwater samples of the study area are earth alkaline water with dominant sulphate and chlorine and normal earth alkaline water with dominant sulphate or chlorine except well no 3 which has been classified as Alkaline water with dominant sulphate and chlorine. Correlation coefficient analyses of the groundwater samples show strong correlations with Ca- Cl and Mg-Cl. TDS shows strong positive correlation relation with Na, Ca, Cl, and SO_4. CA was used to organize the fifteen sampling locations into four clusters with similar water quality parameter CA is divided into four clusters of similar characteristics related to water quality. PCA shows a high positive correlation between groundwater parameters and factor 1which reflects the role of the geogenic process like the dissolution of carbonate and dolomitic rocks prevalent in the study area.

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