Available online www.jsaer.com

Journal of Scientific and Engineering Research, 2017, 4(7):10-24

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Evaluation of Groundwater Quality and its Suitability for Drinking and Agricultural Use of Rural Areas for Zabid Directorate-Wadi Zabid, Hodiedah, Yemen

Shaif M K Saleh[1]*, Sanaa HGh Al-Alaiy[2], Badr I Abdul-Razzak[3], Ghunaim Sh A Nasher[4]

[1]Department of Chemistry, Faculty of Science and Education, Aden University, Yemen
[2]Department of Chemistry, Faculty of Education-Zabid, Hodeidah University, Yemen
[3]Department of Chemistry, Faculty of Education, Hodeidah University, Yemen
[4]Department of Marine Geology,Faculty of Marine Sciences and Environment, Hodeidah University, Yemen

Abstract The objective of the study is to evaluate the Groundwater quality and its suitability for drinking and agricultural uses. Comparison between the measured parameters and the Yemeni standards and WHO guidelines was made to determine the suitable water for the different uses. Chemical index like percentage of sodium, SAR, RSC, PI, CAI, MH and Kelly's Ratio (KR) were calculated. Forty ground water samples were collected from different fields around Zabid directorate. The evaluation of ground water quality in study area was based on 14 parameters such as pH, EC, TDS, TH, Na^+, K^+,Ca^{2+}, Mg^{2+},Cl^-, HCO_3^-, SO_4^{2-}, NO_3^-, Total coliform and Fecal coliform were determined from the groundwater samples. The results showed that the water resources in the study area is generally moderate to very hard as fresh water type (TDS<600 mg/l). The order of major cations are Ca^{2+}>Na^+> Mg^{2+}>K^+, while the major anions as the follows: HCO^-_3>Cl^->SO_4^{2-}>NO_3^-.Water classification of the study area indicate the role of simple dissolution and weathering in the chemistry of water resources of 62.5% of water samples for careless and controlled by bicarbonate, as well as the role of evaporation in the chemical composition of (37.5%) of the samples careless controlled by sulfate and chloride. The results of chemical analyzes showed, may be used for drinking, according to the WHO specifications and Yemeni standard, with the exception of some high nitrate concentrations for some samples. However, the microbiological results showed the presence of coliform "*Escherichia coli*" in (87.5%) of the wells sampled careless which unfit for drinking. In general, it appears that the water quality in the study area is suitable for irrigation uses based on the Na%, SAR, PI and KR values that has been calculated for the water, while according to magnesium hazard values, 63 % samples can cause adverse effect on the agricultural yield.

Keywords Assessment, Groundwater Quality, Water Pollution, WadiZabid, Yemen

1. Introduction

Groundwater is an important source of drinking water for human kind. It contains over 90% of the fresh water resources and is an important reserve of good quality water. Groundwater, like any other water resource, is not just of public health and economic value; it also has an important ecological function [1]. In many groundwater assessment studies, evaluation of the quality groundwater is as important as the quantity, in as much as the usability of groundwater available is determined by its chemical, physical and bacteriological properties. The hydrogeochemical processes reveal the zones and quality of water that are suitable for drinking, agricultural and industrial purposes. Further, they help to understand the changes in water quality due to rock–water interaction as well as anthropogenic influences [2-3].

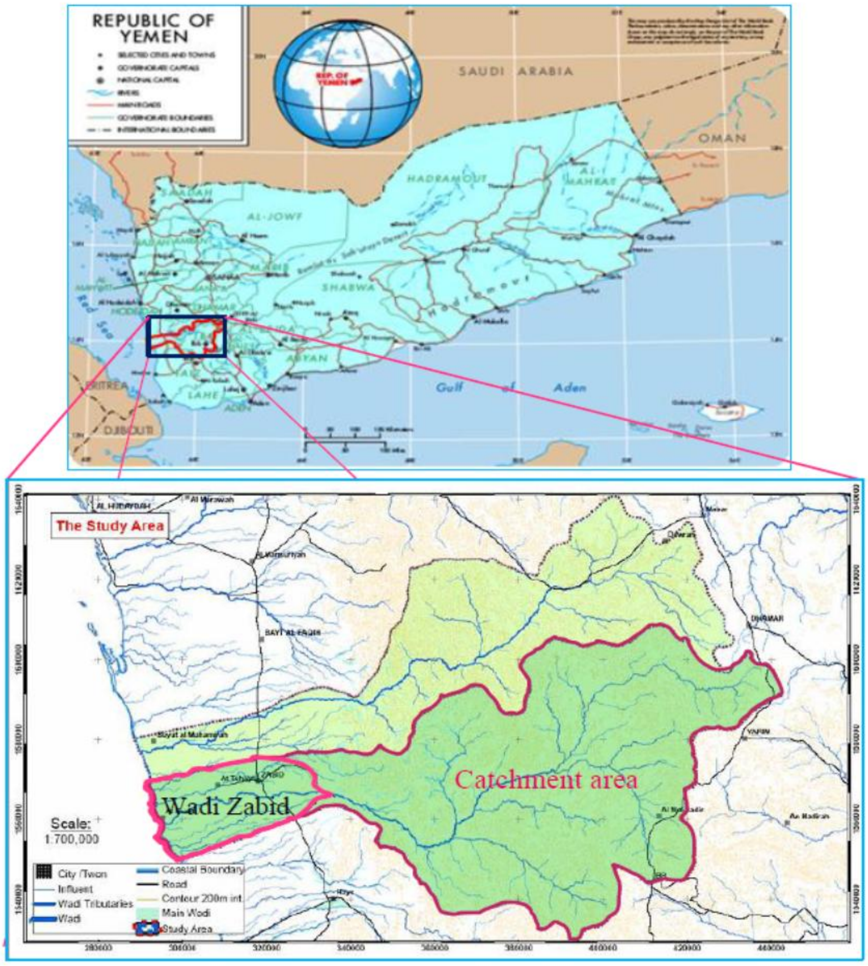

Figure 1: Study Area

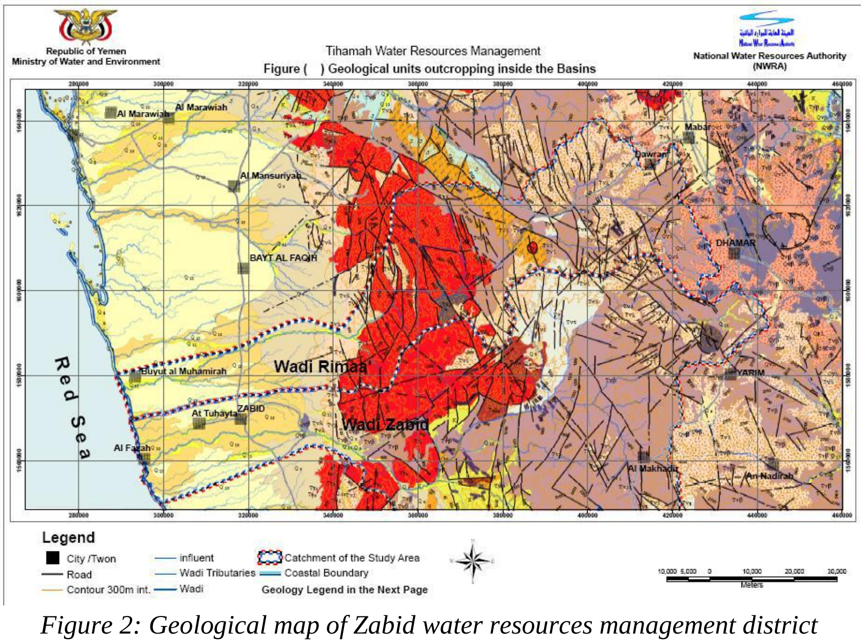

Figure 2: Geological map of Zabid water resources management district

The chemical composition of groundwater is controlled by many factors that include composition of geological structure and mineralogy of the watersheds and aquifers, geological processes within the aquifer, and anthropogenic activities [4-6]. Groundwater is an important water resource for drinking and agriculture uses in study area. Zabid water resources management district suffers from overexploitation as well as mismanagement of the water resources in the district. According to the last well inventory for the district which achieved by National Water Resources Authority (NWRA)in 2006, there were about 7572 operational water points in the district, the total abstraction from these wells are 706,640,496 m^3.The over exploitation in the district causes to deterioration of the water quality in the plain and especially in the downstream areas. The Agricultural area of Zabid is located in the Southern Tihamah agricultural region, according to Tihamah development authority categorization which divided the Tihamah plain into three agricultural regions: northern, middle and southern [7]. The main objectives of the study are as follows: 1) Study the physico-chemical and bacteriological characteristics of groundwater; 2) Assess the suitability of water resources in the study area for drinking and irrigation purposes; 3) Determination of groundwater types; 4) Guidance for community on water use restrictions and safe locations for water wells.

2. Study Area

WadiZabid is one of the seven major wadis, wich from Tihama basin. Catchment area of wadi extends from the Yemen highlands (around Ibb and Yarim) in the east into Tihama coastal plain in the west and drains into the Red Sea. The total catchment area of wadiZabid is about 4630km^2 (Figure 1). The study area comprises the middle part of WadiZabid. This area is located in the southern part of Tehama plain between longitude 297,000 - 335,000 UTM-E and latitude 1558000-1570000 UTM-N. Wadi Zabid is located on distance about 100 km southeast of the Al-Hodiedah port. Zabid water resources management district is an arid district typical of the Tihama region. It receives small amounts of rainfall during summer, with higher temperatures prevailing throughout the year. Rainfall increases at east ward due to the geographic effect of the mountainous areas. The rain fall patterns are influenced by both the Red Sea convergence zone effect and the intertropical convergences zone effect, which produce to main rainfall periods, one from March to May and the other from July to September. Mean annual rain fall amount varies from < 100 mm in the western coastal areas to about 500 mm in the eastern foothills areas [7]. Zabid district is an arid district with high air temperature. The air temperatures vary according to months of the year and the altitude. During the months from May to August the temperature is very high where the maximum air temperature may reach 40 ^oC, while the temperature from September to April becomes moderate at about 18 ^oC. The annual average of air temperature is 29.6 ^oC. Humidity varies throughout the year. The mean monthly humidity is 60-75% [7]. The subsurface geology forms basically a continue which can be divided intotwo broad faces based on grain size, which decreases west-wards as a factor both of degree combination of sediment transport capacity as the Wadi spate is dissipated on route to the sea. Altogether four main physiographic units can be recognized within the land for the coastal plain: Alluvial fan, Alluvial plain (Coarse to medium subsurface deposits), Alluvial sand deposits and Alluvial marine platform (medium to fine subsurface deposits).

Zabid water resources management district is underlain by an extensive alluvial aquifer which ranges in depth from 0-50m in the east, adjacent to the foot hills to 200-300 m at the coast. The evaluation of the aquifer has been mainly controlled by the tectonics associated with development of the Red Sea graven. The aquifer comprising of cobles gravel, sand salt and clays Figure 2 illustrate Geological units of wadiZabid[7].

3. Materials and Methods

Forty groundwater samples were collected from the Middle part of WadiZabid during the first quarter of the year2015, from different fields in the Zabid directorate (Figure 3 & Table 1). Temperature, electrical conductivity (EC) and pH were measured using digital meters immediately after sampling in the field. Water samples collected in the field were analyzed for chemical constituents such as sodium, potassium, calcium, magnesium, chloride, bicarbonate, sulphate, nitrate and bacteriological analysis for total coliform and fecal coliform using the standard methods as suggested by the American Public Health Association [8]. All samples were refrigerated at temperature of 4 ^oC to preserve the cations and the microorganism in the well water before transported to the Laboratory for analyses at the Laboratories of Tihama Development Authority and Sana'a Local Water and Sanitation Corporation (SLWSC). Geographic information systems software (Arcgis 10) were used to draw the map for the location of sampling in the study area, and two programs (Aquachem) and (Excel) were used to analyze and interpret chemical properties of the water in the study area. Evaluation of the water for drinking uses was carried out based on a comparison of the physical, chemical and biological parameters in the water of wells with the drinking water guidelines of World Health Organization WHO and Yemeni Standards. Evaluation of water quality also for agricultural uses was carried out based on Chemical index like percentage of sodium (Na %), SAR, RSC, PI, CAI, Magnesium Hazard (MH) and Kelly's Ratio (KR).

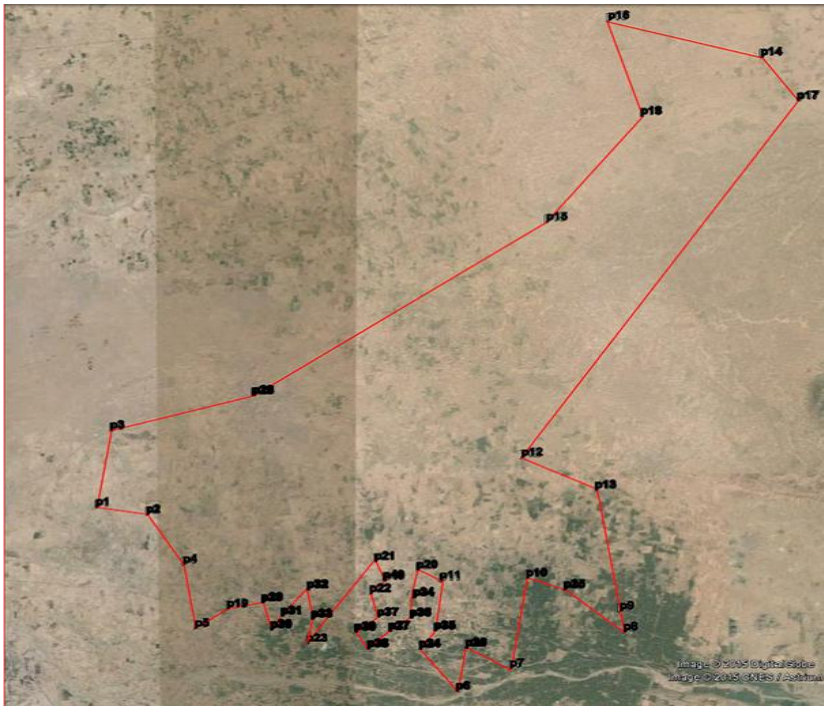

Figure 3: Location map of the studied wells

Table 1: The names and locations of the studies samples

Well No.	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**
Zone	Al-Hema			Al-Quraiah		MahalAl-shaikh		Al-Morshedia
Village	Al-Hann	Al-Aaqel	Al-Hema	Al-HababiAl-Qotebei		Al-Shaikh Al-Hawali		Al-Aorshedia
Well No.	**P9**	**P10**	**P11**	**P12**	**P13**	**P14**	**P15**	**P16**
Zone	Al-Morshedia	Mahal Al-Mubarak			Al-Shabariq		Belad Al-Requod	
Village	Al-Ahmar	Abkargah	Al-Mubarak	Al-Shabariq	Souleiman	Al-Garob	Al-Tawila	Al-Ghoniqa
Well No.	**P17**	**P18**	**P19**	**P20**	**P21**	**P22**	**P23**	**P24**
Zone	Belad Al-Requod		Al-Toraibah					
Village	Al-Modman	Al-Mebraia	Al-Raian			Mahwa Al-Grbi	Al-Raian	
Well No.	**P25**	**P26**	**P27**	**P28**	**P29**	**P30**	**P31**	**P32**
Zone	Al Toraibah				Al-Zareebah			
Village	ProjAl-Raian	MahwaDahmash		Al-Toraibah	Al-Zareebah			
Well No.	**P33**	**P34**	**P35**	**P36**	**P37**	**P38**	**P39**	**P40**
Zone	Al-Zareebah							
Village	Al-Zareebah		Al-Reeqab					

4. Results and Discussion

4.1. Groundwater Chemical Composition

The results of the physico-chemical and microbiological characteristics of the groundwater samples for forty water sources wells in Rural Areas For Zabid Directorate are presented in Table 2. Summary of measured parameters from the study area alongside with WHO [9] and Yemeni Standards [10] approved standard for drinking water is provided in Table 3. The pH values of the studied samples ranged from 6.80 to 8.16 with an average value is 7.53.These results are in within the values for drinking water (6.5 to 9.5) suggested by WHO [11] and local standard. The pH values are within the recommended values of 6.5 to 9 by Yemen's Ministry of Water and Environment [12]. pH values indicate the alkaline water nature in the study area, pH usually has no direct impact on consumers. However, it is one of the most important operational water quality parameters. Most natural waters having values within the range of 6 to 8.5 [13], if the pH is above 7, this will indicate that water is probably hard and contains calcium and magnesium [14]. Electrical conductivity (EC) values were different between samples and its values of the studied samples range from 889 to 2083.33 μScm^{-1} with an average value is 1245.56 μScm^{-1}. Electrical conductivities indicates the amount of ions dissolved in water. According to Langenger [15], the importance of electrical conductivity is its measure of salinity, which greatly affects the taste and thus has a significant impact on user's acceptance of the water as being potable.

The concentrations of total dissolved solids (TDS) showed different results between samples. TDS range from 545 to 1250 mg/l. All of the TDS values obtained in the study area within the maximum permissible level of WHO [9], except the two samples number (15 & 20), but in YS [10] for drinking, all of the studied samples are within the maximum permissible level. Fresh water has TDS less than 1000 mg/l, Brackish water has TDS values range from 1000 to 10000 mg/l [16]. Based on this classification, 95 % of samples are belonging to the falls under brackish water and 5% to fresh water.

Table 2: Physicochemical and microbiological characterization of the studied samples

TC: Total Coliform;

Well No.	pH	E.C μScm^{-1}	TDS	Ca	Mg	Na	K	TH	Cl	HCO_3^-	SO_4^{2-}	NO_3^-	TC (cfu/100ml)	(*E.Coli*)
			Concentration (mg/l)											
P1	7.1	934	598	50	34	76	3.18	265	121	183	109	33	17	-Ve
P2	6.9	1089	697	72	41	90	3.56	350	145	244	149	45	35	-Ve
P3	7.47	1125	675	69	31	62	1	100	35	315	100	24	161	+Ve
P4	7.1	1122	718	80	43	87	4.65	380	156	366	184	44	28	+Ve
P5	7.1	889	569	60	34	66	2.60	290	110	305	102	55	161	+Ve
P6	7.0	1009	646	67	48	82	4.63	375	117	305	164	26	10	-Ve
P7	7.1	988	632	67	35	81	4.22	335	96	366	118	32	161	+Ve
P8	7.1	968	620	66	34	84	4.61	305	92	366	112	36	161	+Ve
P9	7.1	1130	723	86	44	96	4.63	400	113	488	176	33	22	+Ve
P10	7.1	959	614	70	28	83	5.05	290	99	366	164	22	161	-Ve
P11	6.8	1208	773	96	44	98	5.05	425	131	427	181	37	161	-Ve
P12	7.80	1230	738	88	19	69	1.2	107	71	329	125	21	35	+Ve
P13	7.65	1128	677	110	22	64	0.85	132	35	201	90	32	10	+Ve
P14	7.54	1345	807	102	20	74	1.25	122	106	214	100	26	35	+Ve
P15	7.54	2083	1250	173	9	94	1.90	181	213	226	160	33	161	+Ve
P16	7.69	1250	750	120	23	71	1.5	143	106	354	125	28	22	+Ve
P17	7.77	962	577	72	10	55	0.94	82	35	232	50	26	28	+Ve
P18	7.38	1042	625	88	8	71	0.82	96	71	207	80	22	35	+Ve
P19	7.40	1067	640	82	28	66	0.9	110	35	342	110	20	43	+Ve
P20	7.41	1767	1060	155	86	116	1.26	748	212	300	260	22	54	+Ve
P21	7.65	1180	708	96	25	59	0.83	344	212	210	120	45	92	+Ve
P22	8.16	1042	625	78	28	62	1.14	312	106	140	140	19	92	+Ve
P23	7.68	1607	964	53	83	72	0.91	484	283	290	200	24	161	+Ve
P24	7.94	1025	615	74	10	72	1.34	228	70	200	140	21	161	+Ve
P25	7.94	1268	761	102	21	74	1.23	344	106	210	128	27	161	+Ve
P26	7.72	918	551	56	25	99	0.77	244	177	190	130	20	35	+Ve
P27	7.63	1597	958	106	44	99	1.18	448	177	170	210	32	161	+Ve
P28	7.87	908	545	64	20	54	0.8	84	71	293	70	19	28	+Ve
P29	7.98	1253	752	93	30	70	0.68	360	106	210	210	24	161	+Ve
P30	7.77	1252	751	93	32	66	0.76	368	106	210	127	22	35	+Ve
P31	7.69	1463	878	115	41	80	0.98	460	141	250	148	14	54	+Ve

P32	7.77	1647	988	138	43	67	0.62	524	141	260	110	30	92	+Ve
P33	7.71	1543	926	109	46	101	1.46	464	141	220	220	29	161	+Ve
P34	7.79	1477	886	131	36	70	1.28	480	141	250	170	29	54	+Ve
P35	7.78	1135	681	77	29	62	0.87	312	177	190	160	21	161	+Ve
P36	7.55	1375	825	120	43	68	0.90	480	141	250	102	33	92	+Ve
P37	7.65	1508	905	90	42	64	0.81	400	212	190	180	34	161	+Ve
P38	7.78	1302	781	104	31	74	1.23	392	212	210	108	27	161	+Ve
P39	7.62	1553	932	118	49	68	0.90	500	212	290	200	33	161	+Ve
P40	7.61	1475	885	126	49	74	1.02	520	106	290	170	24	92	+Ve

Among the cations, the concentrations of Na, K, Ca and Mg ions ranged from 54 to 116, 0.62 to 5.05, 50 to 172.8 and 7.61to 85.71 mg/l, with average of 75.92, 1.84, 92.92 and 34.12 mg/l, respectively.Ca is a dominant cation. The order of abundance is (Ca^{2+}> Na^{+}> Mg^{2+}>K^{+}). **Among the anions**, the concentrations of Cl, HCO_3, SO_4 and NO_3 lie between 35.45 to 283, 140 to 488, 50 to 260 and 13.64 to 55 mg/l, with average of about 128.48, 265.77, 142.55 and 28.61 mg/l, respectively. The order of abundance of major anions is (HCO_3^->Cl^-> SO_4^{2-}>NO_3^-). They fall within the maximum permissible limit for drinking as per the WHO international standards except nitrate at sample 5. The cation and anion concentrations are defined the hydrogeological setting where the HCO_3, SO_4 dominant anion species of water indicate the recharge characteristics of the study area [17-20]. The concentration of dissolved ions in groundwater samples are generally governed by lithology, nature of geochemical reactions and solubility of interaction rocks. Generally, water in the discharge zones tend to have higher salinity compared to that of there charge areas due to the longer residence time and prolonged contact with the aquifer matrix [16].

Table 3: Summary of measured parameters from the study area alongside with WHO [9] and YS[10] approved standard for drinking water

Parameters	**Units**	**Amount in Groundwater samples (n=40)**				**WHO Standard**	**Yemeni Standard**	
		Min.	**Max.**	**Average**	**SD**		**Most Desirable limits**	**Maximum Allowable Limits**
pH Value	-	6.80	8.16	7.53	0.33	6.5-8.5	6.5-8.5	6.5-9
EC	μScm^{-1}	889	2083	1246	272	---	450-1000	2500
TDS	mg/L	545	1250	758	157	1000	650	1500
TH	mg/L	82	748	325	153	500	100	500
Na^{+}	mg/L	54	116	76	14	200	200	400
K^{+}	mg/L	0.6	5.1	1.8	1.5	---	8	12
Ca^{++}	mg/L	50	173	93	28	100-300	75	200
Mg^{++}	mg/L	7.6	86	34	16	20	30	30-150
Cl^{-}	mg/L	36	283	129	58	250	200	600
HCO_3^{-}	mg/L	140	488	266	76	500	150	500
SO_4^{--}	mg/L	50	260	143	45	250	200	400
NO_3^{-}	mg/L	13.6	55	29	8.5	50	---	50
Total Coliform	(cfu/100 ml)	10	161	94.4	62	Nil	Nil	Nil
E. Coli		-5	+95			Nil	Nil	Nil

4.2. Statistical analysis (*Correlation analysis*)

A correlation analysis is a bivariate method which can be employed to study the degree of relation between tow variables. It is simply a measure to exhibit how well one variable predicts the other [21]. Table 4 shows the correlation matrix for the studied samples. It illustrates that TDS shows a good positive correlation with Cl and Na. TDS and Cl also exhibit a strong positive correlation with Na, Ca, and Mg which indicate these cations are present in a chloridic form. On the other hand, correlations between other ions and TDS and among themselves are positive suggesting significantly that TDS is derived mainly from them. It illustrates that NO_3^- shows a good positive correlation with K^+ which indicate may be due to the migration of leachate from the fertilizer application for agricultural activities in study area.

Table 4: Correlation matrix for the hydrogeochemical data

	TDS	Ca^{2+}	Mg^{2+}	NO_3^-	SO_4^{2-}	HCO_3^-	Cl^-	TH	K^+	Na^+
TDS	1.00									
Ca^{2+}	0.81	1.00								
Mg^{2+}	0.44	0.12	1.00							
NO_3^-	0.02	-0.03	0.11	1.00						
SO_4^{2-}	0.58	0.31	0.68	0.02	1.00					
HCO_3^-	0.09-	0.09-	0.27	0.20	0.11	1.00				
Cl^-	0.62	0.28	0.56	0.22	0.59	-0.17	1.00			
TH	0.84	0.76	0.74	0.05	0.66	0.11	0.55	1.00		
K^+	0.25-	0.32-	0.14	0.42	0.15	0.65	-0.08	-0.12	1.00	
Na^+	0.37	0.25	0.43	0.11	0.63	0.26	0.34	0.45	0.45	1.00

4.3. Hydrochemical Facies

The hydrochemical facies classification is based on the three anions (HCO_3, Cl and SO_4) the cations (Na, K, Ca and Mg) calculated in meq/L, which occur in water as major chemical elements. These classification bases include the diagrams of Piper [22]. The major concentrations of the analyzed samples were plotted on Piper diagram using "Aquachem software as shown in (Figure 4).

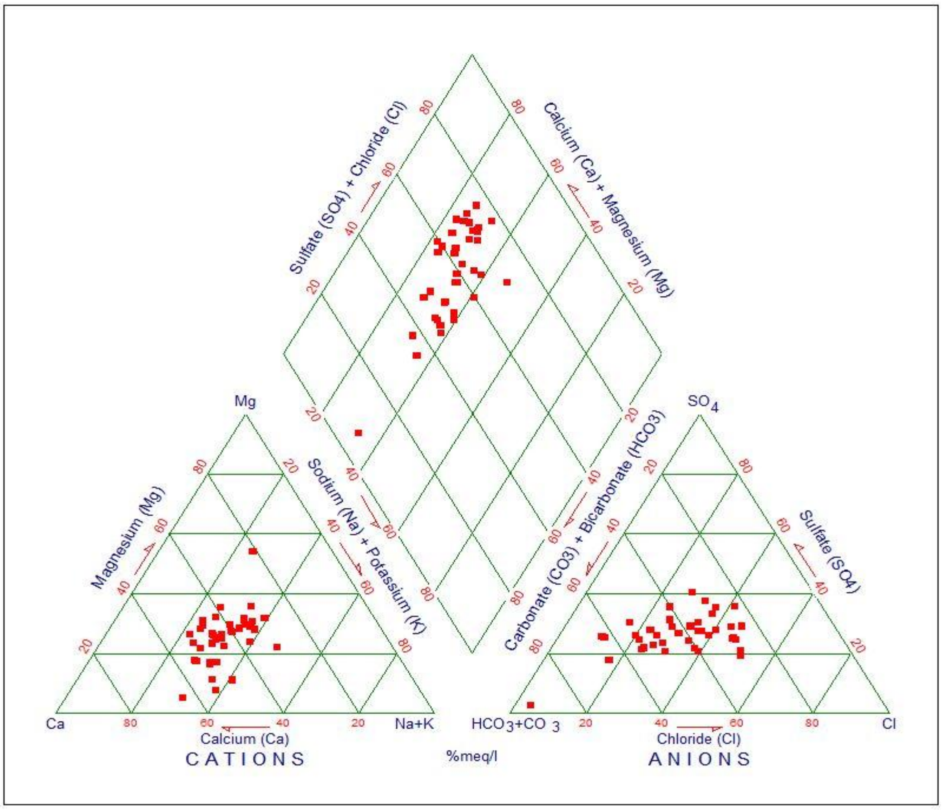

Figure 4: Piper diagram of the groundwater samples in the study area

The plot shows that the groundwater samples fall in the major two fields as follows:

Field 1: earth alkaline water with increased portions of alkalis with prevailing bicarbonate. (62.5%) of the studied water samples are belonged to this field.

Field 2: earth alkaline water with increased portions of alkalis with prevailing sulfate and chloride. (37.5%) of the studied water samples are belonged to this field.

These groundwater types in the study area can be attributed to the broad variations in geological and hydrological setting of the area. It explains the role of evaporation in the water composition as the loss by evaporation results in the transfer of salts from soil water to the soils [23-25]. The study area lies in the arid climate, which leads to a high rate of evaporation especially during summer. It also shows the role of dissolution of carbonate rocks that generate the bicarbonate types.

4.5. Dissolution and deposition

The saturation indices are useful in predicting the extent of water chemical equilibrium with the minerals composing the rock and the dissolution and/or deposition processes during rock water interactions. The SI of a particular mineral can be defined based on the following equation [26]:

$$SI = \log (K_{IAP} / K_{SP})$$

Where K_{IAP} is the ionic activity product and K_{SP} is the solubility product of the mineral. When the SI value equals zero then the water is in equilibrium with respect to a particular mineral. But if the SI is over zero (positive value) then the water is oversaturated with respect to the concerned mineral and that mineral tends towards precipitation, while if the SI is less than zero (negative value) then the water is undersaturated and that mineral tends towards dissolution from the rock matrix. The SI for halite, anhydrite, gypsum, calcite, dolomite and aragonite were calculated using PhreeqC program for windows [27] and are listed in Table (5). The calculated values of SI for anhydrite, gypsum and halite are found within undersaturation state except the sample number (14) for anhydrite. This undersaturation state can be attributed to the hydrogeological and geological setting. The carbonate minerals show oversaturation state in (82.5,80.0,75.0%) of the studied water samples for (dolomite, calcite and aragonite) respectively. suggesting that these carbonate minerals have influenced the chemical composition of the study area The oversaturation state is related to geological setting of the area where carbonate minerals are major component for composition oils in the study area in addition to its high-temperature degree situation and evaporation process [19, 28].

4.6. Drinking and Irrigation Water Quality

The analytical results have been evaluated to ascertain the suitability of groundwater of the study area for drinking and agricultural uses.

4.6.1. Drinking water suitability

The drinking water quality is evaluated by comparing with the specifications of WHO [9] and Yemeni standards [10]. Summary of measured parameters from the study area alongside with WHO and YS approved standard for drinking water is provided in Table 3. To ascertain the suitability of water for any purposes, it is essential to classify the water depending upon their hydrochemical properties based on their TDS values [16, 21]. **TDS** concentration is a secondary drinking water criteria because of its esthetic effect rather than a health hazard. Elevated TDS value indicates that the dissolved ions may cause the water to be corrosive, have salty or brackish taste and it may also indicate that the water contains elevated concentrations of ions that are above primary or secondary drinking water standards such as, nitrate, lead, zinc, etc. 95% of the studied water samples are fresh and 5% of the studied water samples are Brackish according to the classification of Freeze and Cherry [16]. All of the studied samples are within the maximum permissible level of WHO [9], except the two samples number (15&20), but in YS[10] for drinking, all of the studied samples are within the maximum permissible level.

Water hardness measures the amount of divalent cations present in the water especially calcium and magnesium that react with soap to form precipitates. Therefore, hard water requires considerably more soap to produce lather. **The total hardness (TH)** is usually expressed as the equivalent milligrams of calcium carbonate equivalent per liter. In the studied samples the TH values range from 81.52 to 748 mg/l with an average value 324.59mg/l. About 93% of the studied samples have TH within the maximum permissible level of WHO [9] and YS [10] for drinking purposes. The classification of studied samples based on TH shows that they fall in moderately soft to very hard category [29] and are listed in Table (5). At present there are no documented health impacts for pH, temp., major cations and anions except nitrate. But they are used as indication for the immediate environment of the well and spring sites. In the studied samples the concentrations of these parameters are within the maximum allowable limits for drinking water.

Table 5: Water classification on the basis of Hardness [29]

Hardness	Water Class	Representing samples	Number of samples	%Samples
0 – 75	Soft	-	-	-
75 – 150	Moderately	3,12,13,14,16,17,18,19,28	9	22.5
150 – 300	Hard	5,11,15,24,26	5	12.5
> 300	Very Hard	All other samples	26	65

Nitrate is a very important compound to be controlled in the drinking water due to its negative effects on human health especially infants less than two years in age. The high concentration of nitrate in drinking water is toxic and causes blue-baby disease methemoglobinemia in children and is responsible for an increased risk to develop stomach and intestinal cancer if consumed for a long periods [30-31]. The sample number (5) have nitrate concentration exceeding the desirable limit of 50 mg/l based on the WHO [9] and YS [10]. The majority of the studied samples have nitrate concentration exceed 20 mg/l which indicates the role of using fertilizers in agricultural activities in the deterioration of water quality in the study area.

4.6.1.1. Microbiological water quality

According to WHO [31], the examination for *total* and *fecal coliform* indicator organisms is the most sensitive and specific way for assessing the hygienic quality of water, therefore this test was used in this study. *Fecal coliform* bacteria are a group of bacteria which are present in sewage material. The presence of *fecal coliform* bacteria indicates that a fecal source such as animal feedlot run-off, septic tank or cesspool leakage, etc. is in the vicinity. Their presence also indicates that the water may be contaminated with organisms that can cause disease which represents a serious and even deathly health concern. It is recommended by the WHO [32] and YS [10] for drinking water that the count of the total and *fecal coliform* bacteria must be zero in 100 ml (Tables 2 & 3). From the results of this study it was found that all studied samples showed dissimilar counts of *total coliform*and(87.5%) of *E.Coli* in studied samples indicating that the local environment of the well or the springs is the key factor in its biological contamination. From the above result it could be concluded that water resources in the study area are contaminated with coliform bacteria, therefore they are not suitable for drinking unless being treated. Boiling, sun disinfection, or chlorination of the water are possible treatment techniques.

4.6.2. Irrigation water quality

Salinity and indices such as, sodium absorption ratio (SAR), sodium percentage (Na %), residual sodium carbonate (RSC), and permeability index (PI) are important parameters for determining the suitability of groundwater for agricultural uses [33-35].

4.6.2 .1. Sodium Adsorption Ratio (SAR)

Sodium adsorption ratio (SAR) is an important parameter for determining the suitability of groundwater for irrigation because it is a measure of alkali/sodium hazard to crops [21]. The primary use of water resources in the study area is for irrigation purposes. The suitability of water resources for irrigation is contingent on the effect of the mineral constituents of the water on both plant and soil. Salts may harm plant growth physically by limiting the uptake of water through modification of osmotic processes, or chemically by metabolic reaction such as those caused by toxic constituents [36]. Numerous parameters are used to define irrigation water quality. Two criteria were used in this study for evaluating irrigation water quality; total soluble salt content (salinity hazard) and the relative proportion of sodium cations (Na^+) to other cations (sodium hazard). The electrical conductivity is a good measure of salinity hazard to crop as it reflects the TDS of the water. Excess salinity reduces the osmotic activity of plants and thus interferes with the absorption of water and nutrients from the soils [37]. The water resource in the study area is good for irrigation purposes for all types of agricultural activitieswhere all studied samples have low EC values less than 1500 µS/cm [38]. While a high salt concentration (EC) leads to formation a saline soil, a high sodium concentration leads to development of alkaline soil. The sodium or alkali hazard in the use of water for irrigation is expressed in term of sodium adsorption ratio (SAR) which is very important parameter for determining the suitability of water for irrigation because it is a measure of alkali hazard to crops. It can be calculated using the formula [24]:

$$SAR = \frac{\text{Na}}{\sqrt{(Ca + Mg)/2}}$$

Where the concentrations are in meq/L (Table 6). All studied samples have SAR values less than 5indicate that there is no alkali hazard anticipated to the crops [37]. The SAR was plotted on the USA salinity laboratory diagram in which the SAR appears as an index for sodium hazard (S) and EC as an index of salinity hazard (C) (Figure 5). The waters were found mostly confined in one class of water types C3-S1 which means high salinity hazards and low sodium alkalinity hazards that indicates the water resources in the study area are usefulfor irrigation purposes.

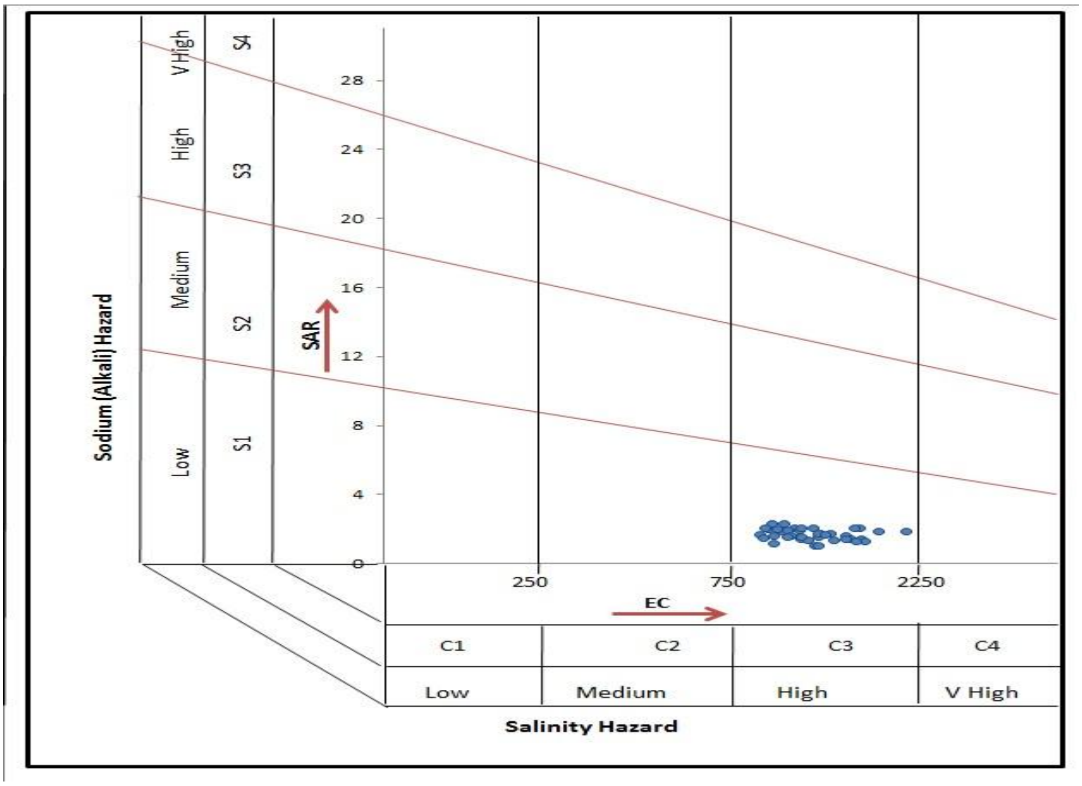

Figure 5: Salinity and alkalinity hazard of irrigation water in US salinity diagram

Sodium percentage (Na%) is also an estimation of the sodium hazard in the use of water for irrigation like SAR, but it expresses the percentage of sodium out of the total cations not as SAR that correlate sodium with calcium and magnesium only. The Na% is calculated using the formula:

$$\text{Na\%} = \frac{\text{Na} + \text{K}}{\text{Na} + \text{K} + \text{Ca} + \text{Mg}} \times 100$$

Where all concentrations are in meq/l. The Na% in the study is less than 40 (Table 6), indicates that the water in the study area is good for irrigation based on Todd classification [36].

4.6.2.2. Permeability Index (PI)

The soil permeability is affected by the long term use of irrigation water as it is influenced by Na^+, Ca^{2+}, Mg^{2+} and HCO_3^- content of the soil. Doneen [39] and WHO [40] gave a criterion for assessing the suitability of ground water for irrigation based on the PI, where concentrations are in meq/L.PI=100×[([Na]+$[HCO_3]^{1/2}$)/[Na]+[Ca]+[Mg].

Accordingly, the PI is classified under class I (>75%), class II (25 –75%) and class III (<75%) orders. Class I and class II waters are categorized as good for irrigation with 75% or more of maximum permeability. Class III waters are unsuitable with 25% of maximum permeability. The PI values in the study area vary from 45% to 87%, with an average value of about 65% (Table 6). According to the permeability index values, 80 % of the samples falls under the class II (PI ranged between 25 and 75 %) and only 20 % belong to class I (PI > 75 %). This indicates that most the groundwater samples are suitable for irrigation.

4.6.2.3. Residual Sodium Carbonate (RSC)

Irrigation water containing large amounts of sodium is of special concern due to effect of sodium on the soil and poses hazards of sodium. Excess of sodium in water which produces the undesirable effects of changing soil properties and reducing soil permeability. Hence, the assessment of sodium concentration is necessary while considering the suitability for irrigation [41]. RSC= $[CO_3^{-2} + HCO_3^{-}] – [Ca^{+2} + Mg^{+2}]$, (where concentrations are expressed in meq/L). Accordingly Carmelita *et al.*, [41], the RSC values is classified under waters suitable (<1.5 meq/L), water marginal (1.5 –2.5meq/L) and water unsuitable (> 2.5meq/L) orders. In the study area the RSC values falls in the range of 0.15 to 6.50meq/L, with an average value of about 4.70meq/L (Table 6). In the study area, 52.5 % of the samples collected showed RSC values lower than 2.5 (suitable and marginal for irrigation), while 47.5 % falls in the unsuitable category with sodium hazard more than 2.5 meq/L. Sodium concentration is important in classifying the irrigation water because sodium reacts with soil to reduce its permeability. Soils containing a large proportion of sodium with carbonate as the predominant anion are termed alkali soils; those with chloride or sulphate as the predominant anion are saline soils [42].

Table 6: Saturation Indices, SAR and other Parameters for the Water Assessment in the Study Area

Well no	SI Anhydrite	SI Aragonite	SI Calcite	SI Dolomite	SI Gypsum	SI Halite	RSC meq/l	CAI-I meq/l	CAI-II meq/l	SAR meq/L	Na %	PI %	MH %	KR meq/L
P1	-2	-0.52	-0.38	-0.58	-1.78	-6.63	0.58	0.01	0.00	2.02	38.88	58.5	53	0.6
P2	-1.76	-0.47	-0.33	-0.56	-1.54	-6.49	2.60	0.03	0.01	2.08	36.31	64.8	65	0.8
P3	-1.92	0.21	0.35	0.72	-1.69	-7.25	1.90	-1.73	-0.20	1.54	33.03	70.1	60	0.6
P4	-1.66	-0.1	0.06	0.2	-1.44	-6.48	4.52	0.11	0.03	1.93	33.83	66.3	64	0.7
P5	-1.97	-0.23	-0.1	-0.1	-1.75	-6.73	3.85	0.05	0.01	1.69	33.05	71.3	65	0.7
P6	-1.77	-0.32	-0.17	-0.14	-1.55	-6.62	3.39	-0.12	-0.03	1.85	33.13	62.7	70	0.6
P7	-1.88	-0.12	0.02	0.1	-1.66	-6.71	5.06	-0.34	-0.07	1.98	36.63	73.6	63	0.8
P8	-1.9	-0.13	0.02	0.09	-1.68	-6.71	4.86	-0.45	-0.10	1.18	37.94	75.2	63	0.8
P9	-1.67	0.07	0.21	0.48	-1.45	-6.58	6.50	-0.34	-0.07	2.08	34.87	69.8	63	0.7
P10	-1.73	-0.12	0.03	-0.01	-1.51	-6.68	5.10	-0.34	-0.07	2.30	39.22	79.1	57	0.9
P11	-1.61	-0.24	-0.1	-0.18	-1.39	-6.51	5.51	-0.18	-0.04	2.05	33.94	66.6	61	0.7
P12	-1.72	0.64	-0.79	1.25	-1.5	-6.91	2.81	-0.52	-0.11	1.01	33.78	78.9	41	0.8
P13	-1.76	0.41	0.55	0.75	-1.51	-7.24	0.15	-1.81	-0.25	1.45	27.62	62.4	40	0.6
P14	-1.75	0.28	0.43	0.49	-1.53	-6.7	0.60	-0.08	-0.03	1.74	32.37	68.4	39	0.8
P15	1.4	0.49	0.63	0.3	-1.18	-6.31	0.64	0.31	0.19	1.88	43.5	65.9	14	0.8
P16	-1.63	0.68	0.83	1.3	-1.41	-6.73	2.41	-0.04	-0.01	1.54	28.21	68.4	39	0.6
P17	-2.12	0.44	0.58	0.63	-1.90	-7.29	2.09	-1.42	-0.23	1.61	35.47	87.1	31	0.9
P18	-1.86	0.07	0.22	-0.28	-1.64	-6.88	1.61	-0.56	-0.17	1.94	32.39	83.3	22	1.1
P19	-1.81	0.24	0.38	0.66	-1.59	-7.23	2.40	-1.90	-0.20	1.59	28.78	72.0	54	0.7
P20	-1.35	0.38	-0.52	1.14	-1.13	-6.24	2.03	0.15	0.05	1.84	24.91	45.2	65	0.5
P21	-1.72	0.34	0.49	0.73	-1.5	-6.51	2.72	0.57	0.33	1.37	27.20	62.6	46	0.6
P22	-1.71	0.59	0.73	1.35	-1.49	-6.78	1.43	0.09	0.03	1.52	33.31	60.5	54	0.6
P23	-1.85	0.2	0.34	1.23	-1.36	-6.31	1.77	0.61	0.33	1.42	24.66	46.7	84	0.4
P24	-1.71	0.51	0.65	0.8	-1.49	-6.89	3.04	-0.59	-0.13	2.29	40.84	84.6	32	1.1
P25	-1.66	-0.65	-0.8	1.26	-1.44	-6.7	2.88	-0.09	-0.03	1.73	32.11	67.3	41	0.7
P26	-1.88	0.14	0.29	0.56	-1.66	-6.35	2.30	0.13	0.08	2.03	32.58	78.1	60	1.2
P27	-1.5	0.24	0.38	0.72	-1.28	-6.37	1.37	0.13	0.05	2.03	32.63	56.4	58	0.7
P28	-2.06	0.56	0.7	1.24	-1.84	-7	2.48	-0.19	-0.05	1.51	32.91	81.4	50	0.7
P29	-1.52	0.62	0.77	1.4	-1.3	-6.73	2.06	-0.02	-0.01	1.74	33.62	61.8	52	0.6
P30	-1.71	0.45	0.59	1.07	-1.49	-6.75	2.42	0.03	0.01	1.04	28.24	59.8	54	0.6
P31	-1.6	0.51	0.66	1.1	-1.38	-6.55	2.81	0.12	0.04	1.62	27.63	56.3	54	0.6
P32	-1.66	0.69	0.83	1.5	-1.44	-6.63	2.95	0.26	0.08	1.27	21.89	50.3	51	0.4
P33	-1.47	0.43	0.58	1.12	-1.25	-6.46	2.12	-0.11	-0.03	2.03	32.32	57.5	58	0.7
P34	-1.46	0.66	0.8	1.39	-1.27	-6.61	3.02	0.22	0.07	1.39	24.33	54.3	48	0.5

P35	-1.69	0.32	0.47	0.58	-1.47	-6.56	2.21	0.45	0.22	1.53	30.50	63.8	55	0.6
P36	-1.74	0.4	0.55	1	-1.52	-6.62	2.74	0.25	0.08	1.35	23.80	52.3	54	0.5
P37	-1.61	0.25	0.39	0.79	-1.39	-6.47	1.73	0.53	0.27	1.39	25.87	53.4	61	0.5
P38	-1.75	0.5	0.64	1.1	-1.53	-6.41	2.49	0.46	0.26	1.70	31.39	60.0	50	0.6
P39	-1.49	0.49	0.64	1.23	-1.27	-6.45	3.18	0.50	0.20	1.32	23.07	51.7	58	0.4
P40	-1.52	0.52	0.67	1.27	-1.3	-6.72	3.20	-0.08	-0.02	1.40	23.75	51.8	56	0.6
Min	**-2.12**	**-0.65**	**-0.80**	**-0.58**	**-1.90**	**-7.29**	**0.15**	**-1.90**	**-0.25**	**1.01**	**21.89**	**45.20**	**14**	**0.4**
Max	**1.40**	**0.69**	**0.83**	**1.50**	**-1.13**	**-6.24**	**6.50**	**0.61**	**0.33**	**2.30**	**43.50**	**87.10**	**84**	**1.2**
Aver.	**-1.64**	**0.24**	**0.31**	**0.69**	**-1.49**	**-6.67**	**2.69**	**-0.15**	**0.01**	**1.67**	**31.51**	**65.01**	**53**	**0.7**

4.6.2.4. Chloro Alkaline Indices (CAI)

It is essential to know the changes in chemical composition of groundwater during its travel in the sub-surface [43]. The Chloro-alkaline indices CAI I, II are suggested by Schoeller [44], which indicate the ion exchange between the groundwater and its host environment. The Chloro-alkaline indices used in the evaluation of Base Exchange are calculated using the Equations:

CAI-I=[Cl–(Na+K)] /Cl and CAI-II=[Cl–(Na+K)]/(SO_4+HCO_3+CO_3+NO_3). If there is ion exchange of sodium (Na^+) and potassium (K^+) from water with magnesium (Mg^{++}) and calcium (Ca^{++}) in the rock, the exchange is known as direct when the indices are positive. If the exchange is reverse then the exchange is indirect and the indices are found to be negative. The reaction is known as a cation-anion exchange reaction. During this process the host rocks are the primary sources of dissolved solids in the water [44]. Indices values of the groundwater samples of the study area are presented in Table 6 that reveal a base – exchange reaction exist all over the area. Chloro Alkaline Indices I, II calculations shows that 50% of the groundwater sample is negative and 50% positive ratios. Groundwater with a base - exchange reaction in which alkaline earths have are been exchanged for Na ions HCO_3> (Ca + Mg) may be referred to a base–exchange–softened water and those in which the Na ions have been exchange for the alkaline earths (Ca + Mg) > HCO_3 may be referred to as base–exchange – hardened water [45].

4.6.2.5. Magnesium Hazard (MH)

In most waters Ca and Mg maintain a state of equilibrium in groundwater. A ratio namely index of magnesium hazard was as calculated by the equation [46-48] as: MH=[Mg^{+2}]×100/[Mg^{+2}+Ca^{+2}], (where, all the ionic concentrations are expressed in meq/L). According to this, high magnesium hazard value (>50%) has an adverse affects on the crop yield as the soil becomes more alkaline. In the study area the magnesium hazard values falls in the range of 14 to 84 %, with an average value of about 53% (Table 6). In the study area, 37 % of the samples collected showed MH ratio <50 % (suitable for irrigation), while 63 % falls in the unsuitable category with magnesium hazard >50 %. The evaluation illustrates that 63 % samples can cause adverse effect on the agricultural yield.

4.6.2.6. Kelly’s Ratio (KR)

Based on KR[49] ground water was classified for irrigation, KR was more than 2meq/L water unsuitable indicating an excess level of sodium in water; water marginal (1 –2meq/L) ; therefore the water Kelley’s ratio of less than 1 was suitable for irrigation. The KR values in the study area vary from 0.4 to 1.2meq/L, with an average value of about 0.7meq/L (Table 6). According to the KR values, 92.5% of the samples falls under the waters suitable (KR value < 1meq/L) and only 7.5 % of the samples under the water marginal (1 –2meq/L). The KR values are below the permissible limit (>2 meq/L) in all the groundwater samples. This indicates that most the groundwater samples are suitable for irrigation.

5. Conclusions

The results of this study provide information that can be useful for the management of the water resources in Rural Areas for Zabid Directorate-WadiZabid especially with respect to water pollution. Interpretation of hydrogeochemical analyses reveals that the water resources in study area is freshwater type and is fall into one class HCO_3-SO_4 water type. Simple dissolution and weathering process controls the water chemistry with major ions abundance is as follows: $Ca^{+2}>Na^{+1}>Mg^{+2}>K^{+1}$ and $HCO_3^{-1}>Cl^{-1}>SO_4^{-2}>NO_3^{-1}$. Although, the physiochemical parameters except nitrate of water resources fall within acceptable limits for drinking purposes with TDS less than 600mg/l, the study showed that water resources are unacceptable microbiological quality due to *fecal coliform* and *total coliform* type of pollutants in water. The study also highlighted the fact that abnormal nitrate concentration as compared with TDS. Deterioration in water quality from anthropogenic activities has resulted from extensive use of fertilizers and sewage water. All studied water samples have low sodium hazard (SAR), salinity hazard Na% less than 40% indicate the suitability of water resources for all types of irrigation purposes. According to the PI and KR values, 80 % and 92.5% of the samples falls under the waters suitable, this indicates that most the groundwater samples are suitable for irrigation. 52.5 % of the samples collected showed RSC values lower than 2.5 (suitable and marginal for irrigation). The CAI indices that the 50% of the samples is negative and 50% positive ratios. MH ratio <50 % (suitable for irrigation), while 63 % samples can cause adverse effect on the agricultural yield.It is recommend not to use the water resources especially those located in the vicinity of houses for drinking purposes unless it is treated properly.

References

[1]. Armon R &Kott Y, (1994). The Health Dimesion of Groundwater Contamination. In Zoller (ed). Groundwater Contamination and Control. Marcl Dekker, INC. New York.

[2]. Elmarkhi, M. , Sadek, S. , Elkharrim, K. , Benelharkati, F. , El Khayyat, F. and Belghyti, D. (2017) Assessment of Groundwater Water Quality in M'nasra (Morocco). J. of Water Res. and Prote., 9, 111-120. doi: 10.4236/jwarp.2017.92009.

[3]. Al-Ramanathan M.K., Rao M.S. & Kumar B. (2006). Identification and evaluation of hydrogeochemical processes in the groundwater environment of Delhi, India. Environ Geol 50:1025–1039.

[4]. Jalali M. (2006). Chemical characteristics of groundwater in parts of mountainous region, Alvand, Hamadan. Iran Environmental Geology 51:433–446.

[5]. Ellis PA. & Rivett MO (2007). Assessing the impact of VOC contaminated groundwater on surface water at the city scale. J ContamHydrol 91:107–127.

[6]. Eneke GT, Ayonghe SN, Chandrasekharam D, Ntchancho R, Ako AA, Mouncherou OF, Thambidurai P (2011). Controls on groundwater chemistry in a highly urbanised coastal area. Int J Environ Res 5(2):475–490.

[7]. NWRA (2009). WadiZabid & WadiRemaa Water Quality, National Water Resources Authority, draft report, Sana'a, Yemen.

[8]. APHA (1999). *Standard methods for the examination of water and waste water*, 20th eden American Public Health Association. Washington.

[9]. World Health Organization (WHO) (2011). Guidelines for drinking water Quality,4th edition, WHO, Geneva.

[10]. Yemen Quality Standards (2000). Yemen Drinking Water Supply. Water Quality Control, Yemen.

[11]. WHO (2004). World Health Organisation. Guidelines for drinking water quality. WHO, Geneva.

[12]. YMWE, (1999). Yemen's Ministry of Water and Environment. Guidelines for drinking water quality. Sana'a, Republic of Yemen.

[13]. Hem J. D. (1970). Study and interpretation of the chemical characteristics of natural water, 2ndedn, U.S. Geological Survey, Water Supply Paper 1473, 363 p.

[14]. David, C. (2004). Small Water Supplies. Cromwell Press, Trowbridge, Wiltshire. India.

[15]. Langenger, O. (1990). *Groundwater Quality in Rural Areas of Western AFRICA*. UNDP-Project INT/81/026, 10 p.

[16]. Freeze R. A., Cerry J. A. (1979).*Groundwater*, Prentice Hall, Upper Saddle River.

[17]. Stuyfzand P. J. (1999). Patterns in groundwater chemistry resulting from groundwater flow. Hydrogeol. J ., 7(1):15–27.

[18]. Toth J. (1999). Groundwater as a geologic agent: an overview of the cause, processes and manifestations. Hydrogeol J. 7(1):1–14.

[19]. Wen X., Wu U., Su J., Zhang Y.&Liu F. (2005). Hydrochemical characteristics and salinity of groundwater in the Ejina Basin, Northwestern China. Environ. Geol., 48:665–675.

[20]. NasherGh, Al-Sayyaghi A., Al-Matary A. (2011). Identification and Evaluation of the Hydrogeochemical Processes of the Lower Part of WadiSiham Catchment Area, Tihama Plain, Yemen. Arabian Journal of Geosciences. Published online.

[21]. Subramani T., Elango L. & Damodarasamy S.R. (2005). Groundwater quality and its suitability for drinking and agricultural use in Chithar River Basin, Tami Nadu, India. Environ Geol. 47: 1099–1110.

[22]. Piper A.M. (1944). Graphical procedure in geochemical interpretation of water analysis. Transactions American Geophysical Union, 25:914–928.https://doi.org/10.1029/TR025i006p00914.

[23]. Drever J.I. (1988). *The geochemistry of natural waters*, 2ndedn. Englewood Cliffs, Prentice Hall, New Jersey.

[24]. Karanth K.P. (1987). *Groundwater assessment, development and management*. Tata McGraw-Hill Publishing Company Limited, New Delhi.

[25]. Rao N.S. (2002). Geochemistry of groundwater in parts of Guntur district, Andhra Pradesh, India. Environ Geol., 41:552–562.

[26]. Lloyd J.W. & Hearhcoat J.A. (1985). *Natural inorganic chemistry in relation to groundwater*. Clarendon Press, Oxford.

[27]. Parkhurst D.L. & Appelo C.A.J. (2003). PHREEQC-a computer program for speciation, batch reactions, one dimensional transport and inverse geochemical calculations. US Geological Survey, Reston.

[28]. Gemic U., Tarcan G., Colak M. & Helvac C. (2004). Hydrogeochemical and hydrogeological investigations of thermal waters in the Emet area (Kütahya, Turkey). *ApplGeochem* 19:105–117.

[29]. Sawyer G. N, McCarty D. L. (1967). *Chemistry of sanitary engineers*, 2ndedn. McGraw Hill, New York, pp. 518.

[30]. Gilly G, Corrao G & Favilli S. (1984). Concentrations of nitrates in drinking water and incidence of gastric carcinomas. First descriptive study of the Piemonate Region, Italy. Sci Total Environ, 34, 35 - 37.

[31]. World Health Organization (WHO) (1993). Guidelines for drinking water quality,2nd edition, Recommendations, WHO , Geneva,pp:8-29 and 120-130.

[32]. World Health Organization (WHO) (1997). Guidelines for drinking water quality, (2nd ed.).Vol. 2. Health criteria and other supporting information. WHO, Geneva.

[33]. Gowd S. Srinivasa, "Assessment of groundwater quality for drinking and irrigation purpose: A case study of Peddavanka watershed, Anantapur District, Andhra Pradesh, India," Environmental Geology, Vol. 48, pp. 702–712. 2005.

[34]. Raju, N. J. (2006). "Hydrogeochemical parameters for assessment of groundwater quality in the upper Gunjanaeru River basin, Cuddapah District, Andhara Pradesh, South India," *Environmental Geology*,

[35]. Hwang, J., Park, S., Kim, H., Kim, M., Jo, H., Kim, J., Lee, G., Shin, I. and Kim, T. (2017). Hydrochemistry for the Assessment of Groundwater Quality in Korea. J. of Agri. Chem. and Envir, 6, 1-29. doi: 10.4236/jacen.2017.61001.

[36]. Todd, D. (1980). *Ground water*. Prentice Hall, London

[37]. Saleh A, Al-Ruwaih F, Shehata M (1999). Hydrogeochemical processes operating within the main aquifers of Kuwait. J Arid Environ 42:195–209.

[38]. Agha W. R. (1987). Hydrology. Damascus University press. Syria (in Arabic).

[39]. Doneen L.D. (1964). Notes on water quality in Agriculture. Published as a Water Science and Engineering Paper 4001, Department of Water Science and Engineering, University of California. Davis.

[40]. [40]World Health Organization (WHO) (1989). "Health guidelines for the use of wastewater in agriculture and aquaculture," Report of a WHO Scientific Group-Technical Report Series 778, WHO Geneva, pp. 74.

[41]. Carmelita, S. N., Thushyanthy M., Barathithasan, T. & Saravanan S. (2010). American-Eurasian J. Agric. & Environ. Sci., 7 (1) 100-102.
[42]. Suresh, T. and Kottureshwara, N.M. (2009). Assessment of groundwater quality of bore wells water of Hospet Taluka region, Karnataka, India, Rasayan. J. Chem. Vol.2, No. 1 , 221-233.
[43]. Aastri, J. C. V. (1994). "Groundwater chemical quality in river basins, hydrogeochemical facies and hydrogeochemical modeling," Bharathidasan University, Thiruchirapalli, Tamil Nadu, India.
[44]. Schoeller, H. (1977). "*Geochemistry of groundwater*," In: Groundwater Studies-An International Guide for Research and Practice, UNESCO, Paris, pp. 1–18.
[45]. Handa, B.K. (1969). *Description and classification of media for hydrochemical investigations*: In: Mithal RS, Singhal BBS (eds) Proc Groundwater Studies in Arid and semi-Arid Regions, University of Roorkee, India.
[46]. Szabolcs, I., & Darab, C. (1964). *The influence of irrigation water of high sodium carbonate content on soils.* In I. Szabolics (Ed), Proc 8th International Congress Soil Science Sodics Soils Res Inst Soil SciAgricChem Hungarian AcadSci, ISSS Trans II, 802-812.
[47]. Paliwal, K.V. (1972).*Irrigation with saline water*. Monogram No.2 (new series). IARI, New Delhi, p 198.
[48]. Raghunath, I. I. M.(1987). *Groundwater*. 2th edition; Wiley Eastern Ltd., New Delhi, India, 344-369.
[49]. Kelly, W. P. (1963). Use of Saline Irrigation Water. Soil Sci., 95 (4), 355-391.