**Research Journal of Chemical and Environmental Sciences**
Res J. Chem. Environ. Sci. Vol 8 [3] June 2020: 20-29
Online ISSN 2321-1040
CODEN: RJCEA2 [USA]

Website: www.aelsindia.com/rjces.htm

**RJCES**

**ORIGINAL ARTICLE**

# Assessment of Groundwater Quality for Drinking and Agricultural Use in AL-Marawa'a District, Hodeidah , Yemen

**Qaid.M.Abdulsalam[1], Ghunaim Sh. A. Nasher[2], Majed. A. M, Al-Edresi[1], Hani A.M.Abdo[1]**
1-Department of Marine Chemistry and Pollution, Faculty of Marine Sciences and Environment, Hodeidah University, Yemen
2- Department of Marine Geology, Faculty of Marine Sciences and Environment, Hodeidah University, Yemen

**ABSTRACT**
*Water quality study carried out in in AL-Marwa'a District for sixteen water samples collected from different locations distributed within the study area. This study aims to assess the suitability of groundwater for drinking and agricultural purposes. Physical, chemical and bacteriological parameters of groundwater such as temperature (T), pH, Total Dissolved Solids (TDS), TH, $Na^+$, $K^+$, $Ca_2^+$, $Mg_2^+$, Cl-, $HCO_3^-$, $CO3^-$, $SO_4^-$, F− , $NO_3^-$ , Fe ,Total Coliform and Chemical index such as Percentage of Sodium (%Na), SAR and EC were calculated based on the analytical results. At most locations the concentration of, Cl , F, NO3 and SO4 exceeded the acceptable limits and other parameters like Electrical conductivity(EC), Total dissolved solids (TDS) and Total Hardness (TH) showed above the desirable limit of WHO and YS Standard for drinking water that requires precautionary measures. while those of pH , $Na^+$ , $K^+$ ,$HCO_3^-$,$Ca_2^+$,Feand Mg fell well within acceptable limit of both WHO and YS standards for drinking water except some Samples which recorded the concentrations higher than maximum acceptable limits according to WHO and YS.The Microbiological results of studied samples identify a suitability of water for drinking purposes. Groundwater of the study area was assessed for irrigation purposes on the basis of Electrical Conductivity(EC), Sodium Adsorption Ratio (SAR ), %Na and Residual Sodium Carbonate (RSC).All water samples have low sodium hazard (SAR) (S1) and high salinity hazard (C3-C4) and Na% less than 60% that indicate the suitability of groundwater for irrigation purposes. all groundwater samples have RSC less than zero indicating that the category of groundwater is good for irrigation purposes.*
***Keywords:*** *Groundwater, Drinking and irrigation water quality, Microbiological Quality,AL-Marawa'a District.*

Received 12.03.2020 Revised 09.04.2020 Accepted 20.05.2020

## INTRODUCTION

To monitor the water resource and ensure sustainability, national and international criteria and guidelines established for water quality standards are being used. [28, 29]. Presently, 85% of the water requirement for domestic use in rural areas, 55% for irrigation and over 50% for industrial and urban uses is met from groundwater [[4, 5]. Groundwater quality has become an important water resources issue due to rapid increase of population, urbanization, lowland,& too much use of fertilizers, pesticides in agriculture [6]. The ground water quality is normally characterized by different physico-chemical characteristics. These parameters change widely due to the various types of pollution, seasonal fluctuation, groundwater extraction, etc. [24]. The assessment of water quality has become an important part of water resource studies, planning and management. It is gaining significant importance due to intense urbanization, industrialization and agricultural activities that are increasing the risk of contamination of soil and water [28].Groundwater is about 20% of the world resource of fresh water and widely used by industries, irrigation and domestic purposes respectively [27]. The water used for irrigation is an important factor in productivity of crop, its yield and quality of irrigated crops. The quality of irrigation water depends primarily on the presence of dissolved salts and their concentrations. Water chemistry differs depending on the source of water, the degree to which it has been evaporated, the types of rock and mineral it has encountered, and the time it has been in contact with reactive minerals [2].

- Study the Chemical ,Physical and Microbiological characteristics in AL Marawa'a District.
- Assess the quality of groundwater used for drinking and irrigation purposes in AL-Marawa'a District.

## MATERIAL AND METHODS

### Study area

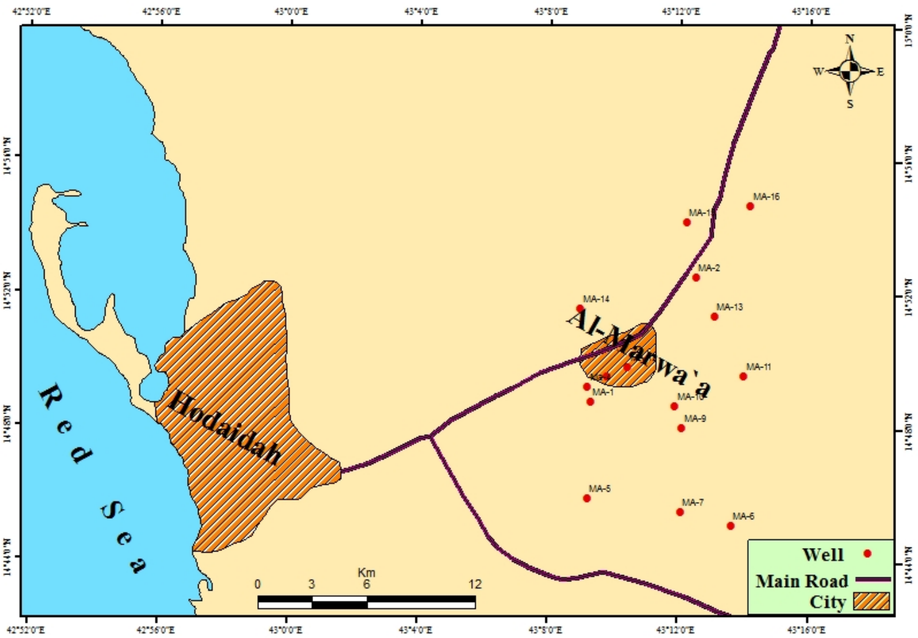
Al-Marawa'a District is located to the northeast of Hodeidah. The studied area is considered apart of WadiSiham catchment area which is a part of the Tehama coastal plain. The geology of WadiSiham, surface drainage system and the deposition of the aquifer material have been greatly influenced by the organic processes, which completely controlled by the tectonic environmental history of the Read Sea Rift System. The outcropping rock in the study area range in age from Tertiary to Recent as shown in the geological map (Fig.2). The oldest rock that crops out on the sides of mountains belong to the Jurassic Kohlan Sandstone Formation (JK), and Amran Limestone Formation (Jas) and to the Cretaceous Tawilah Sandstone Formation (KT). Volcanic rocks composed of mafic and felsic rocks (Basalt, Dacite and Granite rocks) belong to Tertiary crops out at the eastern part of the study area [3].

The Tertiary Medj-zir Sandstone Formation (Tm) which is 120m thick tops the Tawilah Sandstone is partially or completely eroded. It is composed of coarse grained sandstone and irregular intervals conglomeratic layers of rounded to sub-rounded quartz fragments. The Quaternary deposits forming the Tihama coastal plain surface, between Hodiedah Town and mountains can be described as follows: Recent evaporates and loess deposits in the Sabkhas and Marshes along the coast, littoral sand and dunes east of Hodiedah town, eoloian fine to medium sand forms the mobile or fixed dunes in the middle and western parts of the plain, older alluvial deposits (Miocene deposits) of sand-gravels extend along the lower reaches of major wadis, alluvial sand and gravels along the main stream courses and gravel plains and alluvial fans on the front of mountains. The thickness of the Quaternary deposits ranges from a few tens of meters in the intermountain basins to several hundred meters east of the Hodiedah town. Hydrogeologically, Groundwater is abstracted from the Eolio-Alluvial Aquifer. The depth to groundwater varies from 30 to 40 meters. The thickness of aquifer is greatest in the mid and western areas of Tihama Coastal Plain and may reaches up to 300m [8]. The aquifer components are clays, silts, sands, gravels and boulders. The yields of wells range from 16 l/s to 25 l/s with average 22 l/s [34-36].

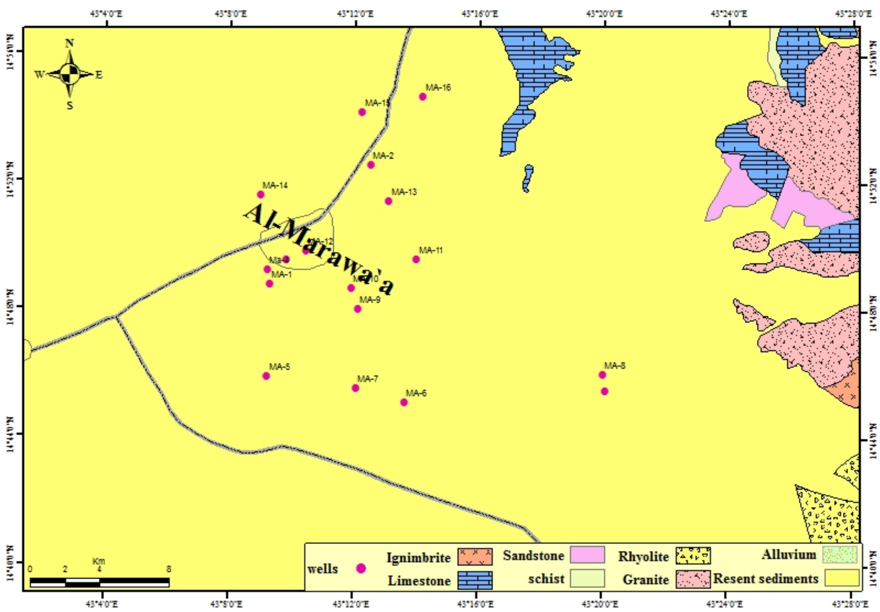
### Sample collection and Analysis

Groundwater samples were collected from (16) various locations within study area
during Marc (2016) Fig.1. Samples were collected in polythene bottles to avoid unpredictable changes in characteristic as per standard procedure [3](Table 1).All the samples were kept in an ice-chest and transported to the laboratory and stored properly at 4 $C^o$. Water quality parameters such as pH , Temperature and electrical conductivity (EC) were analyzed immediately [3]. Groundwater samples were analyzed for calcium ($Ca^{+2}$), magnesium ($Mg^{+2}$), sodium ($Na^+$), potassium (K+), chloride ($Cl^-$), bicarbonate (HCO3-), carbonate ($CO3^{-2}$) sulfate ($SO_4^{-2}$),nitrate ($NO_3^-$) , iron (Fe) ,TH, fluoride ($F^-$) ,Total Coliform ,SAR and Na%.All Samples were Analyzed for Physical ,Chemical and Bacteriological Characterization. samples were analyzed by appropriate certified and acceptable international standard methods (APAH, 1998) and the water quality assessment. Standard Methods for the Examination of Water as shown in (Table 2)$Ca^{+2}$ and $Mg^{+2}$ content was determined by EDTA titration method. $Na^+$ and $K^+$ content was determined by using a Spectrophotometer (HACH). $Cl^-$ concentration was measured by silver nitrate titration. $HCO^3$- and $CO_3^{-2}$ contents were measured by acid-base titration. $SO_4^{-2}$ contents were estimated by turbid metric method using turbidity meter. Groundwater Quality for Drinking Purpose was evaluated in accordance with the drinking water quality standards (WHO,1993, 2004 and YS, 2001).Groundwater quality for Irrigation Purpose was evaluated based on its calculated values of some chemical indexes like sodium adsorption ratio (SAR) and EC (USSL, 1954) and sodium percent (%Na) were classified according to Wilcox (1955). Aquachem and ArcGIS9.1 software programs have been used to manage, create and graphically display the water quality data.




Fig(1) Location map of the study area




Fig(2) Geological map of the study area

## RESULTS AND DISCUSSION

### Hydrochemistry

The results of the physico-chemical and bacteriological characteristics of the studied water samples are presented in Table (1). The pH values range from 811. to 8.37 with an average value is 8.2. pH values indicate the alkaline water nature in the study area. while the field temperature range varies between 24.5 $C^o$ and 25 $C^o$ . electrical conductivities(EC) indicates the amount of ions dissolved in water and its values of the studied samples range from 1144µS/cm to 5850µS/cm with a mean of about 2256µS/cm.The acceptable limit of EC in drinking water is less than 1500 µS/cm [28, 30]. Most of samples show values higher than the prescribed limit. Higher concentrations indicate that the ionic concentrations are more in the groundwater. In the present study TDS range from 743 mg/l to 3508 mg/l.TDS values > 500 ppm indicates the presence of slightly elevated concentrations of salts and is related to the other problems such as hardness [13]. Based on the classification system [4, 6, 8, 19].Some of groundwater samples are generally classified as fresh water (TDS < 1000 ppm).Among the cations, total hardness ranges from 120 to 410 mg/L with a mean of 272.5mg/l .the concentrations of Ca , Mg, Na and K, and ions ranged from 29.6 to 308, 20.64to 193, 84.24 to 744 and 2.1 to 9 mg/l with a mean of 87.3, 61.95, 303.76 and 4.56 mg/l, respectively. The order of abundance is Na >Ca> Mg >>K. Among the anions, the concentrations of Cl , SO4 , HCO3 and $NO_3$ lie between 127.8 to 1555, 70 to 625, 150 to 574 and 1.32 to 155 mg/l with a mean of about 357.7, 310.5, 297.68 and 79 mg/l in respective order. The order of abundance of major anions is Cl>SO4 >HCO3 >> NO3.the concentrations of Fe and Franged from 0to 1.6 and0.29 to 6.65 mg/l with a mean of about 0.1518and1.53mg/l, respectively.

The hydrochemical faces of groundwater in the study area are determined by plotting the concentration of major cations and anions in the Piper (1944) trilinear diagram (Fig. 3). The plots shows that the majority of the groundwater samples fall in the fields of earth alkaline with prevailing sulfate and chloride. This groundwater type in the study area explain 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 [11-14., 18]. The study area lies in the arid climate, which leads to a high rate of evaporation especially during summer.

Table 1:

| Sample no. | pH | EC µS/cm | TDS mg/L | Ca++ mg/L | Mg++ mg/L | Na+ mg/L | K+ mg/L | Fe++ mg/L | Cl- mg/L | CL Mg/L | HCO3 mg/L | NO3- mg/L | F- mg/L | TH mg/L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MA-1 | 7.6 | 1144 | 743 | 29.6 | 32.64 | 84.24 | 3 | 0.24 | 127.8 | 210 | 260 | 8.9 | 1.06 | 120 |
| MA-2 | 7.65 | 1279 | 830 | 40.8 | 35.52 | 107.64 | 2.1 | 1.6 | 163.3 | 230 | 334 | 29.1 | 6.65 | 250 |
| MA-3 | 7.5 | 2450 | 1590 | 89.6 | 20.64 | 219.96 | 3.3 | 0.06 | 333.7 | 70 | 160 | 155 | 2.75 | 310 |
| MA-4 | 7.35 | 2080 | 1353 | 64.8 | 59.52 | 154.44 | 2.7 | 0.08 | 234.3 | 460 | 170 | 136 | 2.25 | 410 |
| MA-5 | 7.44 | 2090 | 1332.37 | 67 | 56 | 348 | 4 | 0.01 | 344 | 275 | 314 | 81.4 | 1.44 | 398 |
| MA-6 | 7.35 | 1644 | 945.21 | 70 | 43 | 218 | 4 | 0.06 | 240 | 87.5 | 292 | 136.4 | 1.03 | 352 |
| MA-7 | 7.28 | 2900 | 1667.45 | 101 | 74 | 400 | 4 | 0.02 | 670 | 175 | 306 | 90.2 | 1.09 | 579 |
| MA-8 | 7.76 | 5850 | 3508.27 | 308 | 193 | 744 | 9 | 0.05 | 1555 | 462.5 | 315 | 79.2 | 1.02 | 1563 |
| MA-9 | 7.25 | 2110 | 1493.54 | 88 | 66 | 336 | 6 | 0.02 | 215 | 512.5 | 298 | 121.4 | 1.3 | 491 |
| MA-10 | 7.25 | 2330 | 1492.09 | 81 | 62 | 385 | 5 | 0.04 | 285 | 398.4 | 446 | 52.8 | 0.48 | 457 |
| MA-11 | 7.17 | 3360 | 2041.50 | 62 | 58 | 616 | 4 | 0 | 387 | 625 | 574 | 1.32 | 1.58 | 393 |
| MA-12 | 7.53 | 2910 | 1848.20 | 143 | 114 | 355 | 7 | 0.11 | 418 | 612.5 | 150 | 124.08 | 0.29 | 826 |
| MA-13 | 7.6 | 1579 | 986.63 | 36 | 29 | 288 | 5 | 0.07 | 155 | 187.5 | 329 | 121.88 | 0.74 | 209 |
| MA-14 | 7.51 | 1544 | 1016.15 | 37 | 38 | 288 | 4 | 0.02 | 184 | 270 | 314 | 38.72 | 0.97 | 249 |
| MA-15 | 7.62 | 1461 | 865.64 | 79 | 60 | 160 | 5 | 0.03 | 205 | 187.5 | 244 | 47.52 | 0.95 | 444 |
| MA-16 | 7.11 | 1380 | 892.97 | 100 | 50 | 156 | 5 | 0.02 | 207 | 205 | 257 | 40.92 | 0.88 | 455 |

Table 1: continue

| Sample no. | Total Bacteria | Fecal coliform | SI Anhydrite | SI aragonite | SI Calcite | SI dolomite | SI Gypsum | SI Halite | SAR | Na% | RSC |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MA-1 | >100 | Nil | -1.97 | -0.15 | -0.01 | 0.38 | -1.76 | -6.57 | 2.54 | 46.38 | -0.83 |
| MA-2 | >100 | Nil | -1.84 | 0.1 | 0.27 | 0.8 | -1.62 | -6.37 | 2.8 | 48.29 | -1.18 |
| MA-3 | >100 | Nil | -2 | 0.01 | 0.16 | 0.02 | -1.82 | -5.76 | 5.52 | 60.54 | -11.28 |
| MA-4 | >100 | Nil | -1.46 | -.0.34 | -0.2 | -0.09 | -1.24 | -6.08 | 2.74 | 45.03 | -7.07 |
| MA-5 | >100 | Nil | -1.67 | 0.05 | 0.19 | 0.65 | -1.45 | -5.56 | 7 | 65.22 | -7.92 |
| MA-6 | >100 | Nil | -2.07 | 0 | 0.15 | 0.44 | -1.85 | -5.91 | 5.19 | 57.15 | -5.49 |
| MA-7 | >100 | Nil | -1.74 | 0.05 | 0.19 | 0.59 | -1.52 | -5.22 | 5.41 | 50 | -18.96 |
| MA-8 | >100 | Nil | -1.09 | 0.87 | 1.02 | 2.19 | -0.87 | -4.63 | 8.19 | 50 | -54.16 |
| MA-9 | >100 | Nil | -1.34 | -0.1 | -0.05 | 0.31 | -1.12 | -5.79 | 6.58 | 59.4 | -5.59 |
| MA-10 | >100 | Nil | -1.47 | 0.06 | 0.2 | 0.63 | -1.25 | -5.6 | 7.8 | 64.4 | -4.79 |
| MA-11 | >100 | Nil | -1.46 | -0.09 | 0.05 | 0.42 | -1.24 | -5.28 | 13.4 | 77 | -4.62 |
| MA-12 | >100 | Nil | -1.13 | 0.07 | 0.21 | 0.66 | -0.92 | -5.49 | 5.36 | 48 | -16.50 |
| MA-13 | >100 | Nil | -2.02 | 0 | 0.14 | 0.53 | -1.8 | -5.97 | 8.65 | 74.4 | -0.79 |
| MA-14 | >100 | Nil | -1.86 | -0.11 | 0.03 | 0.42 | -1.64 | -5.9 | 7.93 | 71.1 | -1.90 |
| MA-15 | >100 | Nil | -1.7 | 0.24 | 0.38 | 0.99 | -1.48 | 6.1 | 3.3 | 43.5 | -5.74 |
| MA-16 | >100 | Nil | -1.57 | -0.15 | 0 | 0.04 | -1.35 | -6.11 | 3.17 | 42.37 | -6.63 |

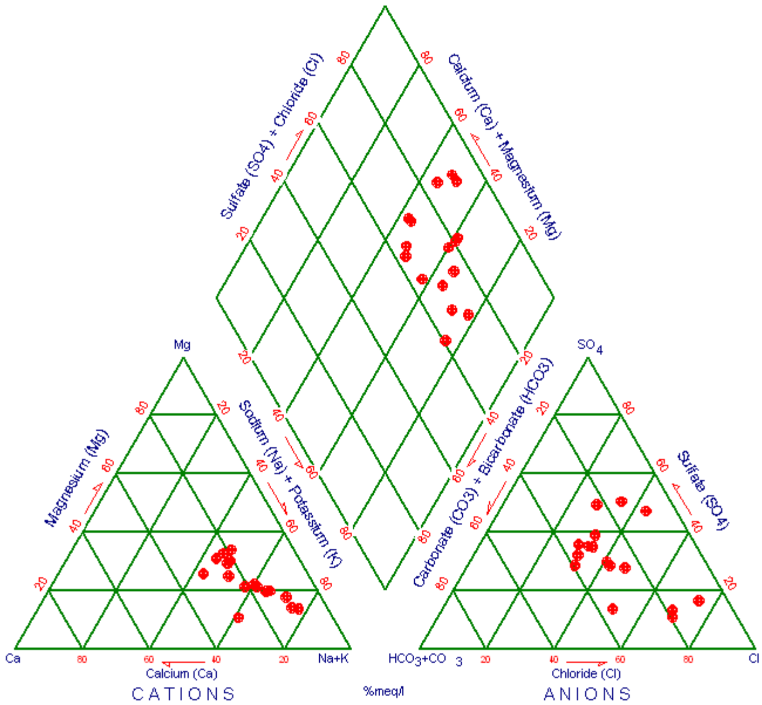


Fig. 3. Piper diagram of the studied samples in the study area.

The saturation indices are used to express the extent of water chemical equilibrium with the minerals composing the aquifer and the dissolution and/or precipitation processes during rock-water interactions. The SI of a particular mineral can be defined based on the following equation [17]

SI = log (KIAP / KSP)

Where, KIAP: is the ionic activity product of the mineral – water reaction.

KSP: 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 under saturated and that mineral tends towards dissolution from the rock matrix.

The SI were calculated using PHREEQC program [19] and are listed in Table (1). The calculated values of SI for anhydrite, gypsum and halite are found within under saturation state whereas carbonate minerals show oversaturation state in dolomite and to a lesser extent calcite and aragonite, 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 soils in the study area in addition to its high temperature degrees situation that exceeds 30$^{o}$C majority of the years. These conditions indicate have a greater influence on the oversaturation state for carbonate minerals where the state of equilibrium between water and mineral phases is a function of temperature [9].

The functional sources of dissolved ions can be broadly assessed by plotting Na/ (Na+Ca) and Cl/ (Cl+HCO3) as a function of TDS [7]. In addition to dissolution and deposition processes another dominant process determining the water composition which is evaporation [7]. From Gibbs diagram (Fig.4) it can be noticed that the evaporation are dominant, and to some extent the chemical weathering of the rock forming minerals factors that control the groundwater chemistry in the study area. Evaporation of surface water and moisture in the unsaturated zone leads to precipitation and deposition of evaporates that eventually leach into the groundwater. This is expected, as evaporation greatly increases the concentrations of ions formed by chemical weathering, leading to higher salinity (TDS). Because the anthropogenic activities also influence the role of evaporation, leading to an increase in these ions in the infiltrating water and thus TDS [10-14], the samples fall in an environment characterized by a semi-arid/arid climate. Such environmental conditions are also responsible for moving the chemistry of the study area towards the zone of evaporation dominance.

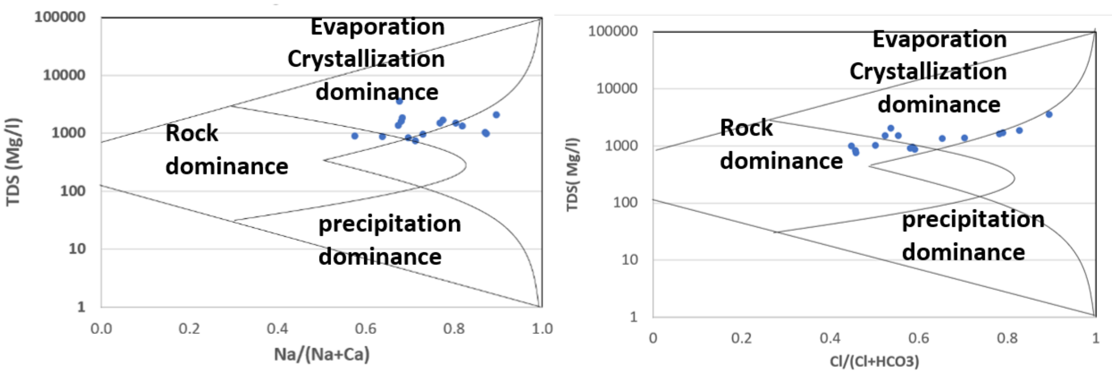



Fig. 4: Mechanisms governing groundwater chemistry [7].

## Groundwater Quality

### Water Quality for Drinking Purpose

Analytical results of physical ,chemical and Microbiological parameters of groundwater Quality (Table 1) were compared with the standard guideline values as recommended by the World Health Organization and Yemeni standards [29-33]. The pH value of drinking water is an important index of acidity, alkalinity and resulting value of the acidic-basic interaction of a number of its mineral and organic components. the pH values in the study area are within the prescribed limit of WHO and YSfor drinking water. The EC depends on the function of dissolved mineral matter content. In the present study The EC values of most water samples are not within the limits of acceptable standard for drinking purpose according to WHO and YS. The higher values of EC in the study area is indicator of higher ionic concentrations, probably due to the high anthropogenic activities in the region and geological weathering conditions acquiring high concentrations of the dissolved minerals. If the TDS is high then EC will be high [2].TDS is sum of the cations and anions concentration ( Sowrabha,2014 ). TDS is due to high dissolved salts of Ca, Mg and Fe. The maximum acceptable limits of TDS in drinking water by WHO,1993 was 1000mg/l. The TDS values of some samples fell within the acceptable standard for drinking water except most Samples which recorded the concentrations higher than maximum acceptable limits according to WHO and YS. The total hardness is due to the presence of divalent cations of which Ca and Mg are the most abundant in ground water [11-16]. In the present study total hardness ranges from 120 to 410 mg/L which recorded the highest and lowest hardness values. The classification of studied samples based on TH shows that they fall in hard to very hard category [20-22].; Calcium ions and Magnesium ions concentrations: There is no adverse health effects specifically attributable to calcium and magnesium in drinking water, But the presence of $Ca^{2+}$ and $Mg^{2+}$ ions in drinking water may result from their ability to cause hardness of water [1]. Water samples in both areas were characterized by low Calcium ion and Magnesium ions contents. Both fell within the [20, 24] maximum acceptable limits for drinking water except some Samples which recorded the concentrations higher than maximum acceptable limits according to WHO and YS. The present area recorded high Chloride ions concentrations of most Water samples. the chloride ions contents varying from 127.8 to 1555mg/l. The highest chloride ions content was recorded in two samples above the maximum acceptable limits according to WHO and YS for drinking water purpose , but according to Dallas and Day [4], chloride ions are non-cumulative toxins, an excessive amount of which, if taken over a period of time can constitute a health hazard [30, 31, 32]. 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 [16]. 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 [8, 27]. most samples have nitrate concentration exceeding the desirable limit of 50 mg/l based on the WHO (1997) and Yemeni standards and except some Samples which recorded the concentrations lower than maximum acceptable limits according to WHO and YS.the majority of the studied samples have nitrate concentration exceed 40 mg/l which indicates the role of using fertilizers in agricultural activities in the deterioration of water quality in the study area [15].The sulphateions of the water samples in the Studied areas within the maximum allowable limits the WHO and YS guidelines of drinking purposes except some samples have recorded the highest sulphate ions content more than 400 mg/l.Iron ions contents: most the water Samples have very low iron concentrations and fell within the WHO the prescribed limit of YS for drinking water Although one samples in the study area recorded iron values higher than the maximum permissible limit. Excess iron value in water may cause taste and odour problem in water and result in red colouration of water

[1]. The concentration of potassium in the study area is low concentrations and fell within the WHO the prescribed limit of YS for drinking water purpose. Sodium is the most important and abundant of the alkali metals in natural waters to which the salinity of the groundwater is directly related, In groundwater source of sodium content is greatly dependent on the rock type of aquifer, Generally most sodium results from natural ion exchange [22]. In the present study The sodium concentrations are ranging between 84.24 to 744mg/l. Although the samples in the study area recorded highest concentrations of Sodium. The Sodium concentrations of samples fell within the maximum permissible limit according to WHO and YS for drinking water purpose except two Samples which recorded the concentrations higher than maximum acceptable limits according to WHO and YS. Most bicarbonate ions in groundwater are derived from carbon dioxide in the atmosphere, carbon dioxide in the soil and dissolution of carbonate rocks. Bicarbonate is an ion that is common to all natural waters because all bicarbonates are water soluble [23]. All samples in the study area have high values of bicarbonate and fell within the maximum permissible limit according to WHO and YS for drinking water purpose except some Samples which recorded the concentrations higher than maximum acceptable limits according to WHO and YS..The fluoride values range from 0.29 to 6.65 mg/l with an average value is 1.53 mg/l .most Samples exceed the maximum permissible limit within WHO and Yemeni standard for drinking water except some Samples which recorded the concentrations lower than maximum acceptable limits according to WHO and YS. . High values of fluoride in the study area can be attributed to the usage of Agriculture fertilizers and the fluoride , containing minerals in the study area through which the groundwater is circulating. bacteriological qualities of groundwater samples are presented in (Table 1).

The Microbiological results of presented study were compared with WHO and YS standards for Drinking Water. All sampled well tested positive to bacteria count. The result indicated TBC of >100 and >1000 cfu/100ml and non of the sampled well showed results that fell within the permissible level for drinking water quality given by the WHO and Yemeni standard. It is recommended by the WHO [30, 31] and the Yemeni standards [33] for drinking water that the count of the total coliform bacteria must be zero in 100 ml. In this study The result indicated the count of the total coliform bacteria 2- 20cfu/100ml.

50% of well water samples were contaminated with total coliform bacteria (table 1).

The level of Total coliform bacteria contamination of water samples may be as a result of the location of the hand-dug well water, domestic animals that normally visit the site to drink and defecate around the well water. These activities could enhance bacterial spores to contaminate the water through the opening of the well. The use of contaminated drawers/ containers to draw water from some well is another source of contamination.

**Water Quality for Irrigation Purposes.**

The suitability of water for irrigation depends on the effects of the mineral constituents of water on both the plant and the soil [19].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 [25]. in the study area 50% of water resources are for irrigation purposes.In this study, Three criteria were used for evaluating water quality for irrigation purpose is mainly based on the following factors; total soluble salt content (salinity hazard) and the relative proportion of sodium cations ($Na^+$) to other cations (sodium hazard).

**Sodium Adsorption Ratio (SAR)**

Sodium adsorption ratio (SAR) is an important parameter for determination of suitability of irrigation water [26] and It is defined by the formula:

$$SAR = \frac{(Na^+)}{\sqrt{1/2[(Ca^{2+}) + (Mg^{2+})]}}$$

Where the ion concentrations are expressed in (meq/l.).The Groundwater Samples were classified in relation to irrigation based on the ranges of SAR values [21], in which the SAR appears as an index for sodium hazard (S) and EC as an index of salinity hazard (C) (Fig.4). In the present study SAR value range from 2.54 to 13.4 with the mean of 5.97.The SAR and EC values of water samples of the study area were plotted in the graphical diagram of irrigated water [30]. Accordingly, most of the entire water sample falls under two class of water types,44% of water sample C3-S1 (High Salinity with Low Sodium) 31% of water sample C3-S2. Two samples located in C4-S2 and one sample in C4-S3(Very High Salinity with medium Sodium and Very High Salinity with high Sodium, respectively) (Fig.4).All The groundwater samples in the study area is generally of excellent class as they all show SAR value of less than10 (fig.4)that indicates the water resources in the study area are useful for irrigation purposes.

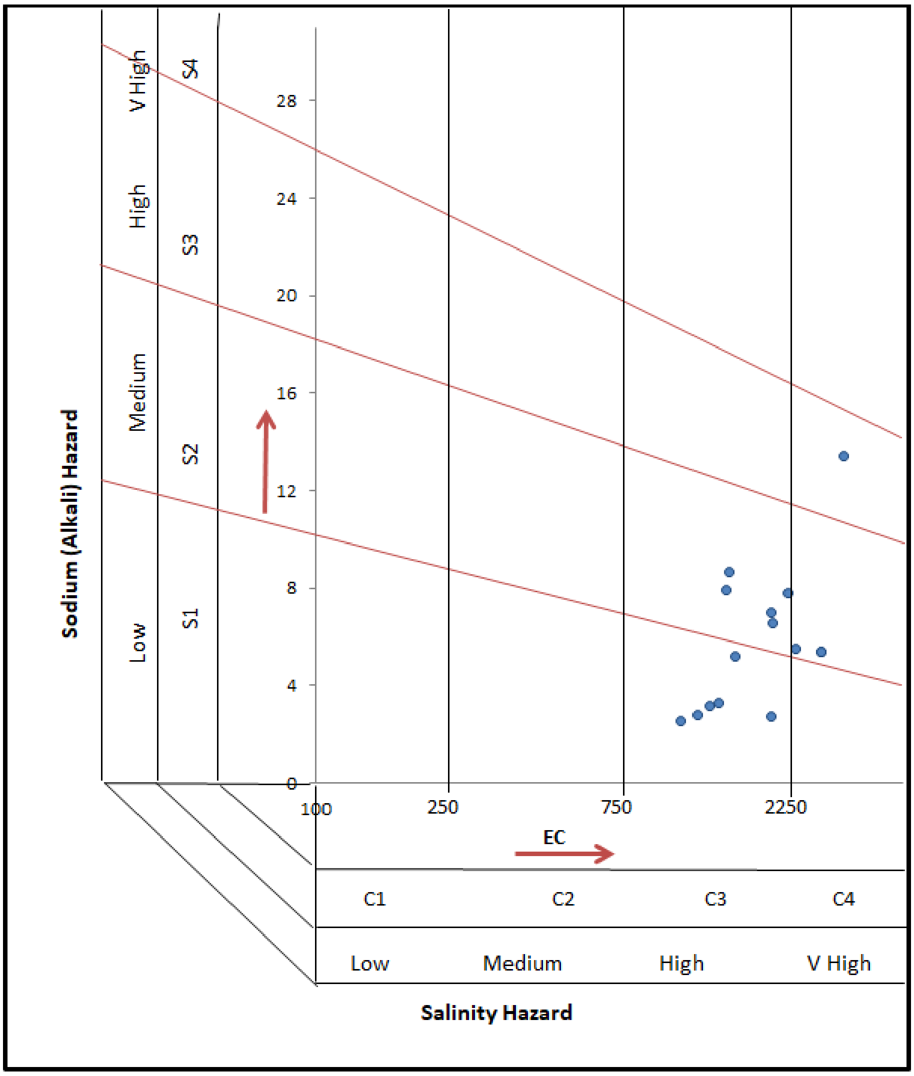



Figure4: U.S. Lab. Classification of irrigation water (after Wilcox, 1955)

**Percentage of Sodium (% Na)**

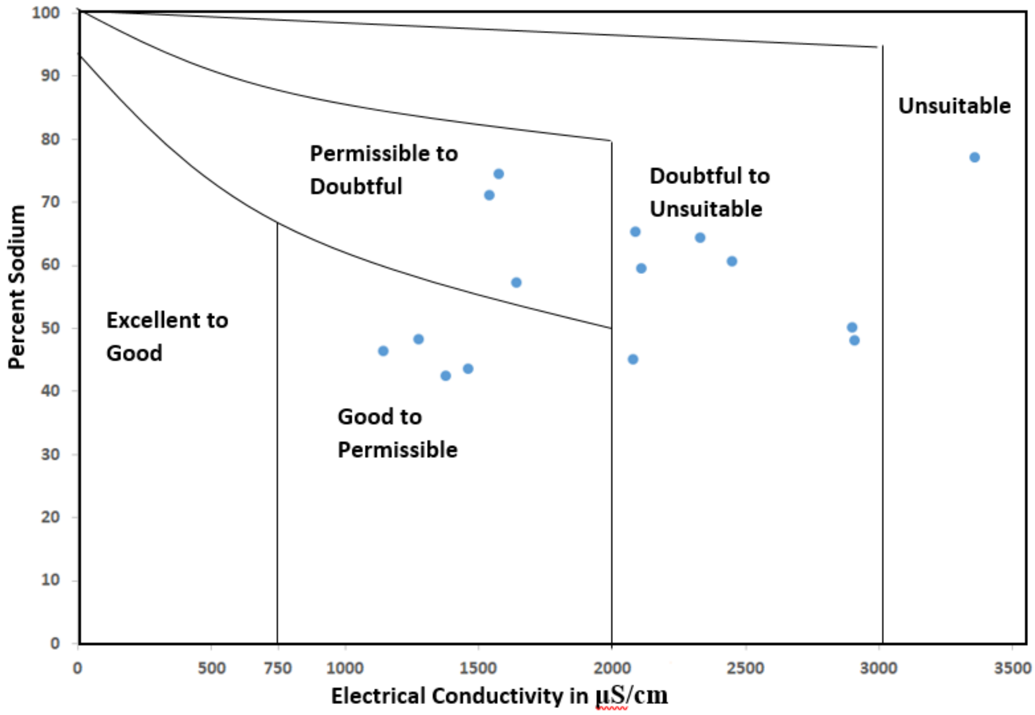
Percent Sodium is another important factor to study sodium hazard and clogging of particles takes place there by reducing the permeability [5, 25].Percent Sodium is calculated by the following formula (Wilcox, 1955):

$\% Na^+ = [(Na^+ + K^+) / (Ca^{2+} + Mg^{2+} + Na^- + K^+) \times 100]$

Where all the ion concentrations are expressed in meq/L.

The percent sodium (%Na)values in the study area varied from 42.37 to 77 (Table 1). According to the classification suggested by Wilcox (1955), 25 % water samples in the study area lie under good to permissible water (750 - 2000 µS/cm) and 19 % under permissible to Doubtful class (2000- more than 3000 µS/cm), 44% water samples lie under Doubtful to unsuitable and one sample is unsuitable for irrigation purposes as shown in Fig. (5).




Fig(5):Classification of Groundwater Samples On The Basis Of Electrical Conductivity and Percent Sodium (After Wilcox, 1955).

**Residual Sodium Carbonate (RSC)**

The residual sodium carbonate (RSC) used to quantify the effects of carbonate and bicarbonate in irrigation waters where the excess sum of them in groundwater over calcium and magnesium influence the suitability of groundwater in irrigation. A high value of RSC in water leads to an increase in the adsorption of sodium on soil (Eaton, 1950). RSC is calculated as follows:

$$RSC = (HCO_3^{-1} + CO_3^{-2}) - (Ca^{+2} + Mg^{+2}) \qquad [20]$$

Where all concentrations are in meq/l.

Carmelita et al., [41], The RSC values is classified groundwater for irrigation purposes with none hazard (<0), low, medium and high hazard with RCS (<1.25, 1.25 – 2.5 and > 2.5) in respective order. Table (1) shows that all groundwater samples have RSC less than zero indicating that the category of groundwater is good for irrigation purposes.

**REFERENCES**


1. Adetunde L.A, Glover R.L.K &Oguntola G.O.2011. Assessment Of The Ground Water Quality In Ogbomoso Township Of Oyo State Of Nigeria. IJRRAS 8 (1).
2. Ananthakrishnan, S., Loganathan, K., Jafer Ahamed, A. 2012. Study on ground water quality & its suitability for drinking purpose in Alathur block perambalur district , Tamilnadu, India. Pp. 1332 1338.
3. Arshid, J., Aasimah T., Yousuf, A.R., Akbar, M. and Aabid, H.N. (2011) Geochemistry and irrigation quality of groundwater along River Jhelum in South Kashmir, India. Recent Research in Science and Technology, 3 (6), 57-63.
4. Dalas H.F and Day J.A (1993): The effect of water Quality Variables on River and ecosystem. Water Research Commission Report No TT61/93.
5. Domenico, P.A., and Schwartz, F.W., (1990), Physical and chemical hydrogeology, New York, Wiley.
6. Freeze, R.A. and Cherry, J.A. (1979). Ground water. Prentic Hall Inc., New Jersey.
7. Gemic, U. Tarcan,G. Colak, M. and Helvac, C. (2004): Hydrogeochemical and hydrogeological investigations of thermal waters in the Emet area (Ku¨ tahya, Turkey). Applied Geochemistry. 19 105 – 117.
8. Ghosh, N.C., and Sharma, K.D., (2006), Groundwater modeling and management, New Delhi.
9. Ghunaim Sh. A. Nasher, Aref A. A. El-Sagheer (2012):Water Quality Evaluation of Bura'a Natural Protected Area, Hodeidah, Yemen. American Academic & Scholarly Research Journal.7, 8-15.
10. G. SrinivasRao, G. Nageswararao (2013). Assessment of Groundwater quality using Water Quality Index. ARCH. ENVIRON. SCI. (2013), 7, 1-5
11. Gibbs, R. J. (1970). Mechanisms controlling world water chemistry. Science, 17, 1088 – 1090.
12. Hem, J. (1989). Study and Interpretation of the Chemical Characteristics of Natural Water, (4th ed.). United States Government Printing Office, Washington.

13. Herojeet, R.K., Rishi, M.S., Sidhu, N., (2013). Hydrochemical Characterization, Classification and Evaluation of Groundwater RegimeinSirsa Watershed, Nalagarh Valley, Himachal Pradesh, India. Civil Environ. Res. 3 (7), 47–57.
14. Jadhav, S.D., Sawant, R.S., Patil, R.S. (2012). Assessment of ground water quality of Ajaratahsil from Maharashtra, India.
15. J.Sowrabha and J.Narayana. (2014). Assessment of ground water quality using for drinking purpose in Shivamogga Town, Karnataka, India. int.J.Curr.Microbiol.App.Sci.2014 3(12): 381-388.
16. Karanth, K. P. (1991). Impacts of human activities on hydrogeological environments. J. GeolSoc India, 38, 195 - 206
17. Lloyd, J.W. and HEATHCOAT, J.A. (1985). Natural inorganic chemistry in relation to ground water. Clarendon Press, Oxford.
18. Pradhan, B., Pirasteh, S., 2011. Hydro-chemical analysis of the ground water of the basaltic catchments: upper Bhatsairegion, Maharastra. Open Hydrol. J. 2011 (5), 51–57.
19. Parkhurst, D.L. and Appelo, C.A.J. (2003). PHREEQC – A computer program for speciation, batch reactions, one dimensional transport and inverse geochemical calculations. US Geological Survey.
20. Ragunath, H. M. (1987). Groundwater. Wiley Eastern Ltd. New Delhi.
21. Raihan, F. and Alam,J. B.:" Assessment of Groundwater Quality in Sunamganj of Bangladesh, Iranian Journal of Environmental Health Science and Engineering, 5(3): 155-166 (2008).
22. Sawyer, G. N. and McCarty, D. L. (1967). Chemistry of sanitary engineers, (2nd ed.). McGraw Hill, New York.
23. Shimaa, M. Ghoraba & A.D.Khan(2013). Hydrochemistry and Groundwater Quality Assessment in Balochistan Province, Pakistan. IJRRAS 17 (2).
24. Tiwari, R.N., (2011). Assessment of groundwater quality and pollution potential of Jawa Block Rewa District, Madhya Pradesh, India. Proc. Int. Acad. Ecol. Environ. Sci. 1 (3–4), 202–212.
25. Todd, D.K., (1980), Groundwater hydrology, 2nd Ed, New York, Wiley, 1-535.
26. Todd, D. (1980). Ground water. Prentice Hall Inc., London.
27. Usha, O., Vasavi, A.S., and Swamy, P.M., (2011), the Physcio Chemical and a
28. Bacteriological Analysis of Groundwater in and around Tirupati, Pollution Research, 30(3), pp 339-343.
29. U.S. Salinity Laboratory, (1954), Diagnosis and improvementof saline and alkaline soils (p. 160), U.S. Dept. Of Agriculture, Hand Book, No. 60.
30. WHO (1984): Guidelines for Drinking Water Quality- Health Criteria and other Supporting Information. World Health Organization, Geneva, Switzerland.
31. WHO (1993): Guidelines for Drinking Water Quality. Vol.1 Recommendation, WHO, Geneva, Switzerland.
32. World Health Organization (WHO). (1997). Guidelines for drinking water quality, (2nd ed.).Vol. 2. Health criteria and other supporting information. World Health Organization, Geneva.
33. Yemen Quality Standards (2000). Yemen Drinking Water Supply. Water Quality Control, Yemen.
34. Al-Absi, A. (2006). Geoelectrical Resistivity Study in Bajil, Al-Marawea'ah and Al-Hujailah areas report. Geological Survey and Mineral Resources Authority, Sana'a, Yemen. (In Arabic)
35. Al-Duba'i, A. (2009). The technical report for drilling four production wells in Tihama basin III. HWSLC. Hodiedah, Yemen. (In Arabic)
36. Ahmad Abdel Warith Consulting Engineers, (2004). Hodiedah Water and Sanitation Local Corporation, Hodiedah Supply Project, Contract No. 1, Completion report of the new wells drilled in Tihama III.

**CITE THIS ARTICLE**

Qaid.M.Abdulsalam, Ghunaim Sh. A. Nasher, Majed. A. M, Al-Edresi, Hani A.M.Abdo. Assessment of Groundwater Quality for Drinking and Agricultural Use in AL-Marawa'a District, Hodeidah , Yemen. Res. J. Chem. Env. Sci. Vol 8 [3] June 2020. 20-29