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Ground Water Chemistry and Quality Assessment of the Dibdibba Aquifer at Safwan- Zubair Area, Southern IRAQ

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Abstract:

Hydrochemical assessment of groundwater was carried out to characterize, classify groundwater and evaluate its suitability for drinking ,irrigation and industrial use in Safwan-Zubair area of south Iraq. Groundwater samples were collected during wet (October ,2016) and dry (April ,2017) seasons from 58 of operated wells (hand dug or tube) for rural water supply using standard sampling procedures. The water samples were analyzed for pH, major ions, total dissolved solids and electrical conductivity (EC), using standard methods. . It was established that groundwater is neutral to alkaline and. The six groundwater types represent (Na_2SO_4) ,(NaCl),($CaCl_2$), ($MgCl_2$) ,($CaSO_4$) and ($MgSO_4$) for both periods. The relative concentrations such as Ca/Mg, Na/Cl, Cl/(HCO_3+CO_3) and base exchange index are used to assess the salinity of groundwater in the study area. This study shows the origin of the water is Marine except well No.8 where is Metrologic. Hydrographical methods (i.e. Schoeller diagram) and AqQA software geochemical modeling program were used to characterize the groundwater quality. Analytical results of groundwater quality in Safwan-Zubair area indicated that the order of abundance of cation concentration were Ca > Mg > Na^+ K and Na^+ K > Mg > Ca in dry and wet seasons respectively while those of the anions were Cl > SO_4 > HCO_3 + CO_3 in both seasons .

Groundwater from Safwan-Zubair area was largely supersaturated with respect to both calcite and aragonite , However, the calculated PCO_2 values suggested that the groundwater system was open to soil CO_2 and that there was possibility of degassing of CO_2 during flow, which could increase the pH and subsequently result in the supersaturation of calcite in both districts. Groundwater water samples were stable towards calcite and aragonite stability field. This suggested that equilibrium of the groundwater with silicates is an important indicator of the hydrogeochemical processes behind groundwater quality in the study area. According to the available standards, the present study samples were unsuitable for drinking purposes but adequate for irrigation purposes depending on Electrical conductivity, soluble sodium percentage (SSP), total dissolved solids (TDS), sodium adsorption ratio (SAR), Kelly's ratio (KR), permeability index (PI) and Magnesium ratio (MAR) values. The values of SAR ,PI , SSP , KR and MAR indicated excellent, good and permissible quality of water for irrigation uses. However, samples with unsuitable SAR (89% during wet season), doubtful to unsuitable PI (76%during dry season) , unsuitable KR (25% during wet season) , The values of MAR During dry 50% of samples and 96.42% during wet fall above the permissible limit of 50 mg/ l indicating the unfavorable effect on crop yield and increase in soil alkalinity and a high salinity hazard values restrict the suitability of the groundwater for agricultural purposes, and plants with good salt tolerance should be selected for such groundwater. A detailed hydro-geochemical investigation and integrated water management is suggested for sustainable development of the water resources for better plant growth, long-term as well as maintaining human health in the study area. while all the samples are corrosive with respect to pH in both seasons period .The corrosivity ratio indicates that all samples are unsuitable for industrial use.

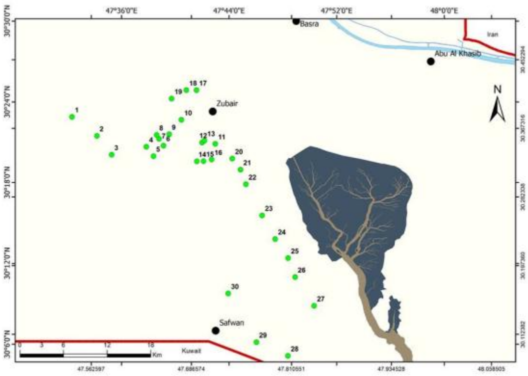
Key words : Hydrochemistry, Groundwater quality, Agriculture use, drinking use, industrial use, Safwan-Zubair ,Iraq

Introduction

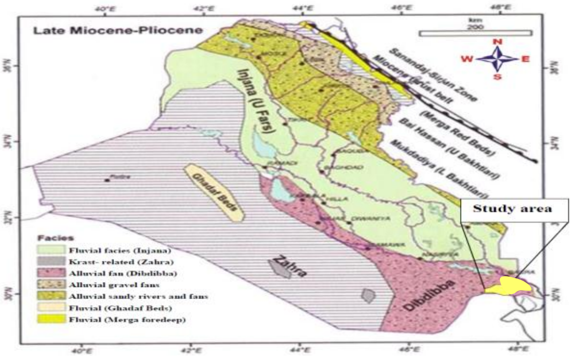
Hydrogeochemical processes in groundwater are broadly controlled by the physical and chemical interactions occurs between the groundwater water and the aquifer materials. Also, they are responsible for the seasonal, temporal and spatial variations of groundwater chemistry and hence the quality (Rajmohan and Elango, 2004; Bolaji and Tse, 2009; Nwankwoala, 2013).Quality of groundwater is equally important to its quantity owing to the suitability of water for numerous purposes(Schiavo et al., 2006; Subramani et al,2005). In turn, groundwater chemistry depends on a many factors, such as general geology, degree of chemical weathering of the different rock types, quality of recharge water and inputs from sources other than water rock interaction. Such factors and their interactions result in a complex groundwater quality (Domenico and Schwartz,1990; Guler and Thyne, 2004; Vazquez Sunne et al.,2005) .The study area lies in the south- west part of Basrah province in the south of Iraq. It locates between longitude line ($47^o30'$– $47^o55'$) and latitude line ($30^o03'$ – $30^o25'$). The considered area is about 1400 km^2 (Fig. 1). The studied area is involved within the Dibdibba plain, which has the characteristics of being sand – gravel soil with rising ground surface level toward the west and southwestern . Dibdibba Formation (Pliocene-upper Miocene age) has a large domain over a wide area in southern part of Iraq (Fig. 2) (Jassim and Coff ,2006) and also it was found in some parts of the middle of Iraq. It has a simple slope in the south of Iraq toward the north-eastern making Dibdibba plain. (Macfadyen, 1938) who was the first to describe the Dibdibba Formation, stated that this formation composes mainly from sand and gravel with some cementing materials such as silt and clay, as it is found in the west of Al – Zubair area . Dibdibba's deposits contain other minerals such as quartz, feldspar, gypsum, and calcite (Al-Dabbas *et al*., 1989) . Rainfall in this area begins in October and continues till May, and the maximum rain values may be attended during January, and vanished during the period between June and August. The average annual rainfall is 148 mm. The maximum average of highest monthly temperature is 46.10 ^oC in August and the minimum is 18.10 ^oC in January. The maximum average of highest monthly evaporation is 453 mm during July and the minimum is 64 mm during January. The maximum and minimum average of monthly relative humidity is (72, 30.5) during January and July respectively. All wells of groundwater developed in Safwan -Al Zubair area penetrate quaternally sediments and then Dibdibba Formation, as mentioned by (Haddad and Hawa, 1979; Al Rawi *et al*., 1983; Al Jawad *et al.* , 1989 ; Kubaisi ,1996; Al-Kubaisi,1999; Al-Suhail,1999;Atiaa,2000;Al-Manssori, 2000; Al- Al-Aboodi, 2003; Al-Suhail et al., 2005) . The groundwater of the Dibdibba aquifer represents the main and lone natural water source in the study area. The Dibdibba aquifer consists of two parts, upper, unconfined, that having brackish water, and lower, semi-confined, with saline water. The two parts separated from each other by a hard clay bed called locally (Jojeb). The two parts are connected

hydraulically, naturally due to the vanishing or local thickness decrease of the separator bed and artificially by penetrating the Jojab by water wells drilling operations. The static water level ranges from 7.24 - 14. m a.s.l.
A groundwater assessment for the upper aquifer in Safwan area was presented by Al-**(**Manhi,2012), he assessment of Twenty-three well are chosen to be sites for hydrochemical sampling. The samples were collected in two seasons, dry and wet, and analyzed to determine the physical and chemical properties and compared with the national, international standards, and different water classifications, to estimate the groundwater suitability for different purposes.

In this study, assessment and hydrochemical study for groundwater include measurements of acidity (pH), electrical conductivity (EC), total dissolved solids (TDS), the concentration of the major cations (Ca^{2+}, Mg^{2+}, Na^{+} , K^{+}), major anions (CO_3^{-2}, HCO_3^{-}, SO_4^{-2} , Cl^{-}) were took place for two seasons dry and wet. The aim of this contribution is to evaluate groundwater quality whereupon can determine its suitability for different uses through comparing certain parameters which are TDS, SAR, SSP, RSC, TH, PI, MR, CAI, K.R, and C.R. with WHO standards and Iraqi standards.



(Fig.1) **Study area and locations of the wells**



(Fig.2) Late Miocene-Pliocene Palaeogeography (Jassim and Coff 2006).

Field and laboratory methods:

In order to adjudge the quality of groundwater, 30 water samples in the dry season (October) and 28 in the wet season (April) seasons, were collected from different of operated wells (hand dug or tube) during the year 2016-2017 (Fig. 1). After pumping for 10 min., samples were collected in good quality screw capped polyethylene bottles of one liter capacity. Sampling was carried out without adding any preservatives in rinsed bottles directly for avoiding any contamination and brought to the laboratory. Only high pure (Anal R grade) chemicals and double distilled water was used for preparing solutions for analysis. Physical parameters like pH, TDS and EC were determined at the site with the help of digital portable water analyzer (WTW). For rest of the analysis, water samples were preserved and bought to the laboratory in minimum period of time and were determined as per standard methods (APHA,1995), Each sample was checked for accuracy by calculating ion-balance, I.B%= [(sum cation –sum anion)/ (sum cation + sum anion)] * 100. It was found that the analytical errors of all samples were less than 5%. The characterization of groundwater samples has been evaluated by means of major ions, Ca^{+2}, Mg^{+2}, HCO_3^{-}, Na^{+}, K^{+}, $Cl^{-}$and SO_4^{-2}. For the identification of water types, the chemical analysis data of the water samples have been plotted on the Schoeller diagram using Geochemistry Software AqQA, version AQC10664 (Rockware AqQA Software **,2011**). In addition, for the evaluation of water quality parameters magnesium and salinity hazard, sodium adsorption ratio (SAR), Soluble sodium percentage (SSP), total hardness (as $CaCO_3$), exchangeable sodium ratio (ESR), Kelly's ratio (KR), permeability index (PI), values of groundwater samples were also determined using AqQA software and some mathematical calculations.

Results and Discussion: Hydrochemistry of groundwater

Results from analysis of selected parameters (physical and chemical) for the dry and wet seasons are presented in (Appendix: 1 and 2). The pH of water provides vital information in many types of geochemical equilibrium or solubility calculations (Hem ,1985). The pH values of the groundwater varies from 7.33 to 8.16 during dry season with an average of 7.66, and 7.09 to 8.02 during wet season with an average of 7.15, which indicates that water is almost slightly alkaline nature of the water. This may be attributed to the anthropogenic activities like sewage disposal and use of fertilizers in the highly populated coastal segment of the study area followed by natural phenomenon like intrusion of brackish water into the sandy aquifers, which initiates the weathering process of underlain geology. The variation in pH values connected with the concentrations of HCO_3^- and its stability in the solutions. Table(13 and 14).All samples during wet season and dry season, were within the range of irrigation water. The conductivity variation gives important information on the evolution of water quality. EC values ranged between 4980 μS/cm to 16050 μS/cm with average of 10154 μS/cm in Dry and varied between 5680 μS/cm to 14380 μS/cm with average of 9386.33 μS/cm during wet. The (EC) value of the wet period is lower than the dry period and this due to dilution process by rainfall. Additionally, the high discharge rates of some wells may cause a significant decrease in groundwater level which may permit the lower part saline water to mixing with the upper part water and causes a considerable increasing in groundwater salinity. The spatial distributions of EC in the studied area for the two seasons controlled by several factors and practices, which may cause on salinity variation within the study area. Some of these factors are the depth of the collected samples, the soil leaching, the long term pumping with high rates of discharge and the distance between the pumping well and the irrigated field. Table(13 and 14).In relation to conductivity, the mineralization of water represented as indicated in Table (1). According to (Detay, 1997) water samples are classified as excessively mineralized water in dry season and Highly mineralized water in wet season .

Table 1: Water classification based on electrical conductivity, (Detay, 1997) and total hardness(Todd,1980).

EC(μc/cm)	Mineralization	Total well	Total Hardness as CaCO3 (mg/l)	Water class
<1000	Very weakly mineralized water		< 75	Soft
1000-2000	Weakly mineralized water		75-150	Moderately hard
2000-4000	Slightly mineralized water		150-300	Hard
4000-6000	Moderately mineralized water		>300	Very hard
6000-10000	Highly mineralized water	28		
>10000	Excessively mineralized water	30		

Total dissolved solids (TDS) comprise inorganic salts and small amounts of organic matters that can dissolve in water. According to (Albu et al., 1997), the (TDS) is determined by multiplying the (EC) by factor (0.64).The TDS values of the groundwater varies from 3714 mg/L to 10272 mg/L during dry season with an average of 6498 mg/L, and 3712 mg/L to 9203.2 mg/L during wet season with an average of 6007.25 mg/L. The difference between TDS values for the two periods may ascribe to the effect of the dilution by the rain water in the wet period. According to (Altoviski, 1962; Drever, 1997; and Todd, 2007) the classification of water based on the TDS, as shown in Table (2). Depending on the comparison of TDS values (Table 13 and 14) with the classifications (Table 2), water samples are considered to be slightly brackish to brackish water in dry season and slightly brackish water in wet season based on classification of irrigation water, all the analyzed groundwater samples above to “brackish water” status for irrigation purpose as their TDS values lie above 1000 mg/L.

Table (2): Classification of water on the basis of the (TDS) (ppm)values

Water class	Altoviski (1962)	Drever (1997)	Todd (2007)
Fresh water	0 - 1000	< 1000	0 - 1000
Slightly water	1000 – 3000	1000 - 2000	------------
Slightly–brackish water	3000 – 10 000	2000 - 20 000	1000- 10 000
brackish water	10000- 100 000	------------	10000- 100 000
Saline water	-------------	35 000	--------------
Brine water	> 100 000	> 35 000	> 100 000

The Total Hardness (TH) of water is a measure of mainly calcium carbonate and magnesium carbonate dissolved in groundwater. TH in the study area ranges between 1800-4300 mg/l during dry season with an average of 2940 mg/l while in wet season it ranges between 2100-4000 mg/L with an average of 2707 mg/l. According to Boyd, 2000 and Todd, 2007, the classification of water based on the TH, as show, TH values for the two periods and the groundwater in the study area considered as very hard water. Table(13and 14). The hardness of the water is due to the presence of alkaline earths such as calcium (Ca) and magnesium (Mg). Ca^{+2} and Mg^{+2} are the most abundant elements in the natural surface and groundwater and exist mainly as bicarbonates and to a lesser degree in the form of sulfate and chloride. Ca^{+2} concentrations are varying from 641-1969 mg/l during dry season with an average of 1127.6 mg/l while in wet season it ranges between 401-2684 mg/l with an average of 797.2 mg/l. Mg^{+2} content is varying from 339 mg/l to 995 mg/l during dry season with an average of 681.13 mg/l, and 456 mg/L to 980 mg/L during wet season with an average of 587.53 mg/l in the study area. Sodium (Na^{+}) and potassium (K^{+}) are generally found in lower concentration than Ca^{+2} And Mg^{+2} in freshwater. The concentration of Na^{+} is varied from 172 to 991 mg/l. (in dry season) with an average of 564.9, and 752 to 2408 during wet season with an average of 1732.6 mg/l in the study area Groundwater with high Na^{+} content is not suitable for agricultural use as it tends to deteriorate the soil. K^{+} is a naturally occurring element; however, its concentration remains quite lower compared with Ca^{+2}, $Mg^{+2}$and Na^{+}. The concentration of K^{+} is observed between 21 mg/l and 130 mg/l during dry season with an average of 59.53 mg/l, and 15 mg/l to 69 mg/L during wet season with an average of 43.39 mg/l in the study area .In comparison with Na^{+}, the low concentration of K^{+} is due to the high resistance of potash feldspars to chemical weathering in the study area. The seasonal variations and the spatial distributions of the mentioned cations controlled by several factors such as lithology, discharge rates and ion exchange. Regarding Ca^{+2} and Mg^{+2}, the calcareous and evaporates materials which are contained in the Dibdibba formation, are considered the main sources of these two cations. The highest concentrations values of Ca^{+2} and Mg^{+2} are located in the western and northwestern of the study area and that may be related to the existence of the Sanam salt plug (5 km west of Safwan), which contains calcareous and evaporates rocks that supply groundwater with considerable concentrations of Ca^{+2} and Mg^{+2}. The spatial distribution of Na^{+} and K^{+} reflects a large variety in their sources where it is suggested that the Dibdibba sandy aquifer sediments that represent the production of the Arabian shield's igneous rocks erosion, contain high concentration of Na^{+} and K^{+} (Sadik, 1977). Additionally, the ionic exchange plays a major role in ion concentrations, (Hem, 1991). The seasonal variation in cation concentrations may be related to the high discharge rates that may cause a mixing with the high salinity water of the lower part of aquifer and as well the dilution by the rain water. The prevailing cation in the groundwater samples is $Na^{+.}$ Bicarbonates are considered the most important component that affects the (pH) of a solution. The process of (HCO_3) depletion to (CO_3) in solution becomes high when the (pH) is more than (8.2), but when the (pH) is less than (8.2) the hydrogen ions are added to the carbonate and become dissolved bicarbonate (Davis and Dewiest, 1966). The main source of carbon dioxide species that produce alkalinity in surface or groundwater is the CO_2 gas fraction of the atmosphere, or the atmospheric gases present in the soil or in the unsaturated zone lying between the surface of the land and the water table (Ljungberg, 2004).The value of HCO_3 is observed from 122 to 414 mg/l during dry season with an average of 216.16 mg/L while in wet season it ranges between 109.8 to 295 mg/l with an average of 201.52 mg/L., higher concentration was noted during dry season. Being the abundant anion in the groundwater its dissolution into the groundwater is mainly due to the dissolution of silicates and rock weathering. Contribution is also made by atmospheric CO_2 and CO_2 released from the organic decomposition in the soil (Subba Rao, 2002). Concerning to HCO_3^-, it was the minimal anion in the groundwater samples. HCO_3^- concentrations affects by pH value and the availability of CO_2 in the air and in the soil's unsaturated zone. The HCO_3^- concentrations may also affected by the carbonate rocks of Jabal Sanam where the highest concentrations located in the northwest part of the study area. Sulfate is one of the major anion occurring in natural waters. The sulfate ion causes no particular harmful effects on soils or plants; however, it contributes to increase the salinity in the soil solution.. Sulfate ion varied from 688 to 4646 mg/L during dry season with an average of 2697.53 and 1936 to 5292 mg/L during wet season with an average of 2845.7 periods . The results show that $SO_4^=$ represents the dominant anion in the groundwater samples in the two seasons and that means there is an existence of a permanent source of SO_4^{-2} ion and that is attributed to the evaporate minerals like gypsum and anhydrite that existing in the Dibdibba formation sediments. Jabal Sanam that contains evaporate and carbonate rocks represents a probable source of SO_4^{-2}, especially that the highest concentrations of SO_4^{-2} in groundwater located on the west and northwest parts of the study area (the closest to Jabal Sanam). Also, the agricultural activities represent another source of $SO_4^=$. Seasonally, the concentrations in the dry period were higher than that of the wet period and that ascribed to the dilution by the rain water. The origin of chloride in groundwater may be from diverse sources such as weathering, leaching of sedimentary rocks and soils, intrusion of saltwater, windblown salt in precipitation, domestic and industrial waste discharges, municipal effluents, etc. (Karanth, 1987). Chloride concentration in groundwater samples in the study area ranged from 1688 to 4748 mg/L with an average of 2803 mg/L and 1249 to 5523 with an average of 3454.33 mg/L during dry and wet seasons respectively. The excess of chloride in the water is usually taken as an index of pollution and considered as tracer for groundwater contamination (Loizidou and Kapetanios ,1993). In natural waters, the concentration of Cl^- bears strong correlation with the Na content and specific conductance. Chloride determinations may serve to indicate the intrusion of waters of different composition or to trace and measure rates and volumes of water mass movements and forms NaCl, whose excess presence in water makes it saline and unfit for drinking and irrigation purposes. Here too, as exhibited by contours, the chloride value decreases during wet season . Regarding Cl^-, its concentration shows an increase the dry season compared with the wet season, due to the mixing with the lower part water of the Dibdibba aquifer where the high pumping rates in this period cause a decreasing in the groundwater level which allows the lower high saline water to moves upward and mixing with the upper part water. In the wet season that generally represents the low pumping rate period, the mixing processes expected to be at the lowest rates, and in spite of the considerable concentration of Cl^- in the rain water but it did not reach the high concentration as in the dry season. (Appendix: 1 and 2).

Hydrochemical formula and water type:

The term hydrochemical facies is a function of solution kinetics, rock-water interactions, geology and contamination sources used to describe the quantities of water that differ in their chemical composition. The groundwater quality is simply the result of the geology and hydrology of the area (Stevanovic and Iurkiewicz , 2009). The water type determining is very important to determine its suitability for the different uses (human, agricultural and industrial).Therefore the type of groundwater in the study area is determined according to Kurolov formula .This formula depends on the ratio of the main ions, (cations and anions) expressed by epm % that are arranged in descending order which have more than (15%) ratio of availability. (Ivanov,et al., 1968).From Appendix (3,4) which explain hydrochemical formula and water type for water samples of study area , the hydrochemical Kurolov formulas for water quality in the study area are represented by six groups determined as shown in Table (3) the hydrochemical formula and water type for the samples in the study area for the dry and wet seasons respectively. The tables illustrate the predominance of the $CaCl_2$ water type ((36.63 of the samples) in the dry period while in the wet period, the predominate water type is NaCl (85.68%). Eight wells in the dry period and one in wet period are of ($MgCl_2$) water type which represents the second water type in the study area with a ratio of (26.64%) and (3.57%) respectively, The remainder of wells varies between($CaSO_4$), ($MgSO_4$) and (Na_2SO_4)water type for both periods . Generally the salts distribution in the area is attributed to the lithology of recharge regions and the study area as a result of weathering and dissolution actions of rocks and clay minerals, in addition to the agricultural and human activities. it is clear that the difference in water quality between both dry and wet seasons occur as a result of recharge and dilution processes in the wet season.

Table (3) Predominant salts of water samples in the study area

Dry season			
HydrochemiclFormula(water type)	Predominant salts	Frequency	Occurs Ratio(%)
K-Na-Mg-Calicium-HCO_3-SO_4-chloride	$CaCl_2$	11	36.63
K-Na-CaMagnesium-HCO_3-SO_4chloride	$MgCl_2$	8	26.64
K-Na-Ca-Magnesium -HCO_3-Cl-Sulphate	$MgSO_4$	7	23.31
K-Na-Mg-Calicium-HCO_3-Cl-Sulphate	$CaSO_4$	4	13.32
Wet season			
K-Ca-Mg-sodium-HCO_3-SO_4-chloride	NaCl	24	85.68
K-Ca-Mg-sodium-HCO_3-Cl- Sulphate	Na_2SO_4	1	3.57
K-Na-Ca- Magnesium -HCO_3-Cl-Sulphate	$MgSO_4$	1	3.57
K-Mg-Na-Calicium-HCO_3-SO_4-chloride	$CaCl_2$	1	3.57
K-Na-Ca-Magnesium-HCO_3-SO_4-chloride	$MgCl_2$	1	3.57

Hydrochemical indicators:

The groundwater of Safwan -Al-Zubair area is characterized by their wide variation in TDS and EC over its area. This variation can be attributed to the litho logical and mineralogical contents of Dibdibba Formation or to the spatial variation in controlling factors that are responsible for sedimentation and dissolution of different minerals. The groundwater samples in the study area are divided into two types, the first is marine water and the second is meteoric water .Chloride ion used to know the geochemical behavior for main elements by the ratio of main elements to chloride because (Cl^-) is the most dissolve ion and less influenced by physical and chemical changes in water. In addition, it is not influenced by adsorption process and exchange of ion by the clay minerals (Levy and Kearney , 1974). If the indicators are greater than one then the water is from meteoric origin and less than one is for water from marine origin (Ivanov et al., 1968). Tables (4,5) shows the hydrochemical indicators for water samples of study area for both periods .It is clear the values of hydrochemical indicators are greater than one which means the ratio of sulfates exceeds the chloride ratio and the origin of groundwater is meteoric in well No.(8),. This reflects that the chloride ion is the prevailing ion and the origin of groundwater is marine. This can be attributed to the existence of a deep recharge from the deeper aquifers in these wells. The value of (rNa/rCl) indicator in the wells No.(8) is greater than one in wet season except all the wells rest in both seasons whose indicators are less than one are for water from marine origin which means a high and strong dilution but it dose not exceed one. The difference is due to recharge processes and the artesian pressure of the deep wells in addition to drawn from meteoric water.

Table (4) Hydrochemical ratios of the water samples of the Dibdibba aquifer in dry season

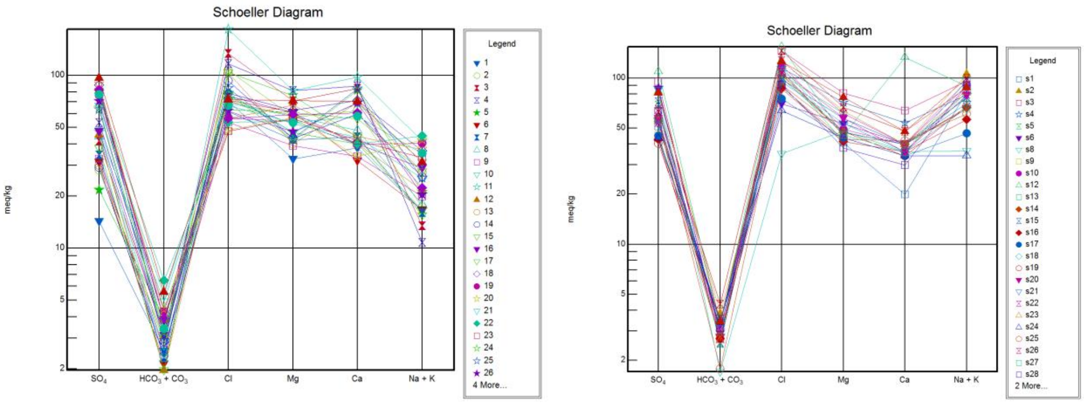
Well. NO.	rNa/rCl	rMg/rCl	rk/rCl	rCa/rCl	rSO4/rCl	HCO3/CL	Cl-Na/Mg	origin
1	0.18	0.47	0.04	0.53	0.2	0.036	1.73	Marine
2	0.13	0.54	0.02	0.58	0.26	0.028	1.58	Marine
3	0.08	0.53	0.01	0.62	0.31	0.025	1.7	Marine
4	0.06	0.7	0.02	0.74	0.45	0.032	1.32	Marine
5	0.18	0.59	0.02	0.5	0.27	0.05	1.35	Marine
6	0.2	0.86	0.02	0.44	0.43	0.03	0.91	Marine
7	0.24	0.69	0.01	0.71	0.56	0.038	1.09	Marine
8	0.24	0.85	0.01	0.69	0.63	0.034	0.88	Marine
9	0.35	0.74	0.02	0.63	0.61	0.049	0.87	Marine
10	0.33	0.73	0.01	0.61	0.67	0.069	0.89	Marine
11	0.21	0.44	0.01	0.52	0.25	0.013	1.76	Marine
12	0.29	0.84	0.01	0.56	0.64	0.0284	0.83	Marine
13	0.25	0.39	0.01	0.67	0.29	0.0289	1.9	Marine
14	0.26	0.46	0.009	0.64	0.31	0.025	1.55	Marine
15	0.14	0.74	0.005	0.42	0.36	0.019	1.15	Marine
16	0.36	0.8	0.01	0.52	0.63	0.041	0.78	Marine
17	0.41	0.97	0.02	0.88	1.28	0.05	0.59	Marine
18	0.45	0.8	0.01	0.91	1.11	0.038	0.67	Marine
19	0.69	0.98	0.01	0.71	1.36	0.081	0.3	Marine
20	0.85	1.2	0.02	0.7	1.66	0.095	0.12	Marine
21	0.38	0.61	0.02	0.9	0.86	0.069	1	Marine
22	0.8	1.03	0.03	0.75	1.47	0.126	0.18	Marine
23	0.66	1.2	0.03	0.88	1.67	0.088	0.27	Marine
24	0.26	0.55	0.006	1.06	0.83	0.043	1.32	Marine
25	0.28	0.51	0.01	0.99	0.75	0.035	1.37	Marine
26	0.3	0.77	0.02	1.12	1.14	0.064	0.9	Marine
27	0.63	1.21	0.02	0.79	1.57	0.071	0.3	Marine
28	0.36	1.07	0.02	1.08	1.46	0.071	0.59	Marine
29	0.5	0.8	0.02	0.87	1.16	0.053	0.61	Marine
30	0.41	1	0.02	0.97	1.33	0.082	0.58	Marine

Table (5) Hydrochemical ratios of the water samples of the Dibdibba aquifer in wet season

Well.NO.	rNa/rCl	rMg/rCl	rk/rCl	rCa/rCl	rSO4/rCl	HCO3/CL	CL-Na/Mg	origin
1	0.9	0.45	0.01	0.22	0.57	0.04	0.2	Marine
2	0.99	0.44	0.01	0.37	0.78	0.04	0.01	Marine
3	0.65	0.55	0.008	0.43	0.65	0.02	0.62	Marine
4	0.67	0.62	0.01	0.46	0.75	0.026	0.51	Marine
5	0.71	0.58	0.01	0.37	0.65	0.025	0.49	Marine
6	0.91	0.75	0.01	0.57	1.23	0.043	0.11	Marine
8	1.01	1.36	0.01	1.02	2.41	0.05	-0.01	Meteoric
9	0.62	0.46	0.01	0.39	0.44	0.035	0.811	Marine
10	0.74	0.4	0.007	0.33	0.46	0.025	0.62	Marine
12	0.57	0.294	0.005	0.86	0.7	0.023	1.45	Marine
13	0.73	0.37	0.007	0.32	0.39	0.03	0.69	Marine
14	0.71	0.51	0.01	0.43	0.63	0.033	0.54	Marine
15	0.77	0.58	0.009	0.4	0.73	0.027	0.38	Marine
16	0.64	0.48	0.009	0.414	0.49	0.035	0.74	Marine
17	0.59	0.58	0.02	0.45	0.606	0.047	0.69	Marine
18	0.68	0.56	0.01	0.37	0.59	0.033	0.56	Marine
19	0.63	0.45	0.008	0.32	0.38	0.034	0.788	Marine
20	0.703	0.51	0.007	0.32	0.51	0.032	0.56	Marine
21	0.69	0.47	0.01	0.39	0.53	0.037	0.65	Marine
22	0.73	0.47	0.01	0.31	0.5	0.025	0.54	Marine
23	0.63	0.5	0.01	0.31	0.43	0.022	0.72	Marine
24	0.51	0.68	0.02	0.53	0.67	0.056	0.71	Marine
25	0.68	0.48	0.008	0.47	0.62	0.02	0.65	Marine
26	0.77	0.41	0.006	0.32	0.49	0.032	0.52	Marine
27	0.81	0.38	0.01	0.3	0.47	0.03	0.48	Marine
28	0.99	0.41	0.006	0.32	0.69	0.035	0.01	Marine
29	0.68	0.6	0.009	0.37	0.64	0.028	0.51	Marine
30	0.67	0.45	0.009	0.32	0.43	0.032	0.7	Marine

Groundwater Quality:

Ground water quality is defined by the chemical constituents in the water and the chemical analysis data are helpful for determining the usefulness of ground water as a potable resource. Rock Work, Software has been employed to calculate and plot the concentration of chemical constituents of ground water samples of both period using (Schoeller ,1960) diagram is used to present concentration chemical composition of groundwater in the study area. The concentration of ions in meq/l shows in Fig. 3 (A and B). Its shown all the boreholes have lower values of bicarbonate (alkalinity) whose amount is directly dependant on the availability of organic substances and pH of the precipitation water. The ions Ca, Mg, Na, and SO_4 show considerable variations. The different patterns may reflect the evolutionary stages of water in the fractured aquifer of Dibdibba formation or mixed waters. The analysis of how major ions compounds are distributed in the fractured aquifer helps to interpret the aquifer mechanics and reveals flow paths and potential recharge areas.



(A) (dry season) Ca > Mg > Na+K andCl > SO_4 > HCO_3 + CO_3(B)(wet season)Na + K > Mg > Ca and Cl > SO_4 > HCO_3 + CO_3

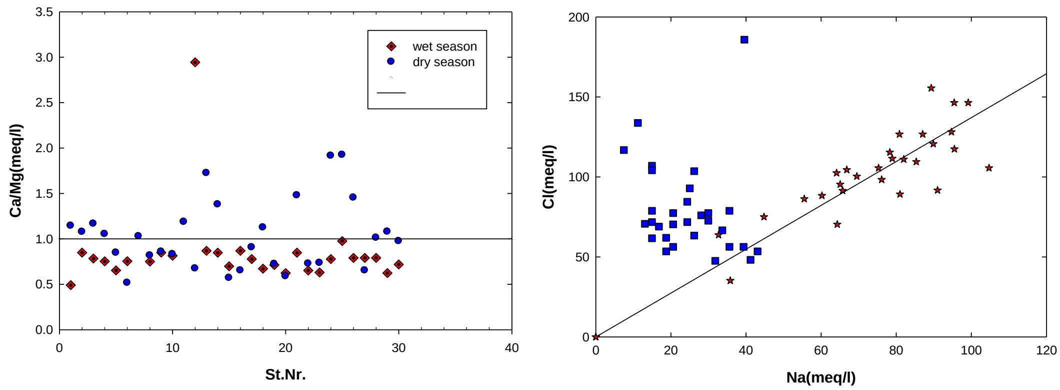
Figure3(A , B):Schoeller diagram showing average composition of major cations and anions in meq/l of the groundwater in study area

Identification of hydrogeochemical processes:

Reactions between groundwater and aquifer minerals have a significant role on water quality, which also useful to understand the genesis of groundwater (Cederstorm, 1946).The hydrogeochemical data are subjected to various conventional graphical plots to identify the hydrogeochemical processes operating in the aquifer region of study area. Some of the possible identified processes are explained below. The ratio of Ca^{+2}/Mg^{+2} has been used to determine the sources of calcium and magnesium ions into the groundwater environment (Maya and Loucks, 1995). If the Ca^{+2}/Mg^{+2} ratio=1, indicates dissolution of Dolomite and > 2 reflects an effect of silicate minerals that contributes calcium and magnesium to the groundwater (Katz et al., 1998). Majority of samples (50%) during dry season fall below 1 ratio line indicating precipitation of Ca^{+2} as $CaCO_3$ which results in a decline of Ca^{+2} values or ion exchange process (Fig. 4A). A total of 26% of samples fall near and above the 1 ratio line indicating ion exchange with Na^+ resulting in an increase of magnesium ions. A total of 2% of the samples lie above the ratio line 2, indicating the effect of silicate minerals. During wet season 96% of samples below 1 ratio line and less than 4% of sample represents above ratio line 2. The ion exchange between the groundwater and its host environment during residence or travel process can be verified, using an index of Base Exchange (Schoeller, 1965, 1967) known as chloro-alkaline indices (CAI). When Na^+ and K^+ ions in water are exchanged with Mg^{+2} or Ca^{+2} ions in weathered materials, the index value will be positive indicating Base Exchange, whereas low salt waters give negative value indicating chloro-alkaline disequilibrium. This is also known as cation– anion exchange reaction. During this process, the host rocks are the primary sources of dissolved solids in the water (Adrian et al., 2007). The CAI during wet season point out 93% of samples favor Base Exchange hardened waters and 7% of samples designate Base Exchange softened waters. During dry season all the samples favor Base Exchange hardened waters. Hence, irrespective of seasons majority of the collected water samples have higher alkaline earth than HCO_3^- indicating base exchange- hardened water. The Na^+/Cl^- ratio has been used to identify the sources of salinity in groundwater environment (Fig. 4B). Na^+/Cl^- molar ratio greater than 1 reflects Na^+ released from silicate weathering (Meybeck, 1987; Stallard and Edmond, 1983) due to rock water interaction via reaction: $\mathbf{2NaAlSi_3O_8 + 9H_2 + 2H_2CO_3 \leftrightarrow Al_2Si_2O_5(OH)_4 + 2Na + 2HCO_3^- + 4H_4SiO_4}$

A total of 4% of samples during wet season reflect the above process. The remaining samples irrespective of season's points lower Na^+/Cl^- ratio, due to the dominance of Cl^- ions. Chloride ions are

present in the groundwater as sodium chloride. Chloride content exceeding sodium may be due to the Base Exchange phenomena or due to pollution by anthropogenic activities (Jones et al., 1999).Being a granitic/gneiss terrain, possibility of chloride bearing minerals like Sodality and Chlorapatite is negligible. Hence, chloride in groundwater is mostly due to Base Exchange of Na^+ for Ca^{+2} and Mg^{+2} or due to agricultural return flow. Agricultural return flow water is characterized by higher ratios of SO_4^{-2}/Cl^- (> 0.05) attributing to the application of gypsum fertilizers (Vengosh et al., 2002)



A B

Figure 4 (A,B): Major ion relationship of Ca^{+2}/Mg^+ and Na^+/Cl^- molar ratio.

Mineral Saturation Index:

Calculated saturation indices (SI) of the water samples (using Aq.QA soft-ware) showed super -saturation (SI>0) with respect to calcite an aragonite (Table 6). The values of SI for calcite and aragonite range from 0.919 to 1.841, 0.755 to 1.677 and 0.506 to 1.269, 0.332 to 1.105 with averages of 0.7, 0.4 and 0.8, 0.6 for dry and wet seasons respectively. In about 100% of the groundwater samples the saturation of aragonite, calcite, was more than zero, indicating oversaturation with respect to these minerals due to evaporation, and therefore, they are precipitated(Srinivasamoorthy et al., 2008).The concentrations of carbonates are caused by the CO_2 present in the soil zone formed by the weathering of rock materials due to alternate wet and dry conditions. The log p_{CO2} values in groundwater range from -3.013 to -1.896 with an average of -2.02 irrespective of seasons, which is higher than the atmosphere (-3.5) indicating decay of organic matter and root respiration as sources (Njitchoua et al., 1997). Since the dissolved CO_2 gas pressure of the waters is higher than that of the atmosphere; the waters are supersaturated with respect to carbonate minerals.

Table6: Statistical characteristics values of the SI of the selected minerals and log Pco2 in the study area

NO.well	Saturation Index					
	Dry period			Wet period		
	Calcite	Aragonite	$logPCO_2$(atm)	Calcite	Aragonite	Log PCO_2(atm)
1	1.229	1.065	-2.710	0.714	0.550	-٢.٢٩٤
٢	1.233	1.068	-2.481	0.653	0.488	-١.٨٩٦
٣	1.121	0.9567	-2.209	0.595	0.430	-٢
٤	1.228	1.064	-2.210	0.809	0.644	-٢.٢١٢
٥	1.367	1.203	-2.490	0.696	0.532	-٢.٢٩٧
٦	0.9673	0.803	-2.724	0.898	0.734	-٢.٣٦٤
٧	1.101	0.9364	-2.636			
٨	0.9195	0.7552	-2.470	0.663	0.498	-٢.٥٩٦
٩	1.019	0.8544	-2.560	0.873	0.709	-٢.١٨٤
١٠	1.531	1.367	-2.460	0.497	0.332	-٢.٠٢٢
١١	1.48	1.316	-2.749			
١٢	1.106	0.9418	-2.867	1.26	1.09	-٢.١٨١
١٣	1.834	1.669	-3.013	0.963	0.799	-٢.٣٠٧
١٤	1.48	1.316	-2.908	0.776	0.611	-٢.٢٣٧
١٥	1.114	0.9499	-2.862	0.815	0.650	-٢.٤٠١
١٦	1.31	1.146	-2.675	0.506	0.341	-٢.٠٢١
١٧	1.157	0.9931	-2.430	0.851	0.687	-٢.١٩٧
١٨	1.151	0.9865	-2.406	0.921	0.757	-٢.٣٦٤
١٩	0.9963	0.8319	-2.098	0.873	0.708	-٢.٢٣٩
٢٠	1.158	0.994	-2.307	0.699	0.534	-٢.٠٩٦
٢١	1.841	1.677	-2.544	0.616	0.451	-١.٩٣٩
٢٢	1.302	1.137	-2.052	0.732	0.568	-٢.١٩٣
٢٣	0.9478	0.7835	-2.108	0.605	0.440	-٢.١٦٨
٢٤	1.343	1.179	-2.394	1.269	1.105	-٢.٥٦٨
٢٥	1.489	1.325	-2.633	1.244	1.08	-٣.٠٩٥
٢٦	1.337	1.173	-2.311	1.015	0.850	-٢.٣٦٧
٢٧	1.016	0.8512	-2.209	0.881	0.717	-٢.٢٥٤
٢٨	1.488	1.323	-2.517	0.928	0.764	-٢.٤٤٠
٢٩	1.153	0.9884	-2.312	1.059	0.894	-٢.٣٥٠
٣٠	1.229	1.065	-1.917	0.831	0.667	-١.٩٠٣
Max	1.841	1.677	-1.917	1.269	1.105	-١.٨٩٦
Min	0.919	0.755	-3.013	0.506	0.332	-٣.٠٩٥

Drinking water quality:

The World Health Organisation (WHO) (2008) and Iraqi standards(IQS) (2009) has set pH, TDS, Cl¯, SO42¯, Mg2+ and Na+ standards for suitability of water for drinking purposes. The results show that in all the samples are exceeding the allowable limit and hence, all of the selected groundwater samples found to be unsuitable for drinking purposes, (Table 7)

(Table 7)measured values of present study compared with IQS,2009 and WHO,2008,permissible limits for drinking water

parameters	Present study Range ppm	IQS,2009 ppm	WHO,2008 ppm
pH	7.09-8.16	6.5-8.5	6.5-8.5
TDS	3712-10272	1000	1000
Ca	401-2684	150	75
Mg	339-995	100	100
Na	172-2408	200	200
K	15-103		12
Cl	1249-5523	350	250
SO_4	688-5292	400	250

Groundwater suitability for agriculture purpose:

The productivity of agricultural crops depends on the quality of plants, its resistance to environmental conditions, its ability to retain water ,the properties of the soil structure , the irrigation method used and other factors . The plants tolerance for total dissolved solids and electrical conductivity in water which uses in irrigation are different depends on the quality of plants (Todd, 1980) .According to classification proposed by Todd (2007) as shown in Table (8). This quality of irrigation water requires specific crops to get good production. The crops are divided into three groups according to salt concentrations and depending on electrical conductivity (EC). Regarding above values, the groundwater of study area (zubair- Safwan) can be used in irrigation under many conditions: High permeability of soil, Good drainage, crops resisting saline water. Application a new irrigation technique water quality depending on electrical conductivity (EC) is suitable for irrigation as:

Group-1: EC = (10020 – 16050μmhos/cm). Groundwater is suitable for high salt Tolerance like date palm, spinach, Garden beets, and cotton Sugar beet Barley (grains).

Group-2: EC = (6530 – 9970 μmhos/cm). Groundwater is suitable for medium salt tolerance like Sunflower, Corn (field) Rice, Wheat, (grain)

Group-3: EC = (4980- 5810 μmhos/cm). Groundwater is suitable for low salt tolerance like Cucumber, Peas, Onion Carrot Potatoes, Sweet Corn, Lettuce Cauliflower, Bell pepper, Cabbage, Broccoli, Tomato, Field beans.

Table (8) Todd classification (2007) for the tolerance of crops by relative salt concentrations for agriculture

Crop Division	Low Salt Tolerance crops **Ec (μS /cm)**	MediumSalt Tolerancecrops **Ec (μS /cm)**	High Salt Tolerance crops **Ec (μS /cm)**
Fruit Crops	0-3000,Lemon, Strawbrry, Peach Spricot,Almond, Plum Orange,apple, pear	3000-4000,Cantaloupe, Olive, Fig,Pomegranate	4000-10,000,Date palm
Sample No.dry	-	-	7,8,9,12,13,14,15,16,17,18,19,24,25
Sample No.wet	-	-	6,8,9,13,14,15,16,17,18,19,21,24,25
Vegetable Crops	3000-4000Celery,Radish ,Green beans	4000-10,000Cucumber, Peas, Onion Carrot,Potatoes,Sweet,Corn,Lettuce,Cauliflower,Bellpepper,Cabbage,Broccoli, Tomato	10000-12,000,Spinach, Garden beets
Sample No.dry	-	7,9,12,13,14,15,16,17,18,19, 25	1,2,3,4,5,6,10,11,20,21,22,23,26,27,28,29,30
Sample No.wet	-	6,8,9,12,13,14,15,16,17,18,19,21,24,25	1,2,3,4,5,10,20,,22,23,26,27,28,29,30
Field Crops	4000-6000,Field beans	6000-10,000,Sunflower, Corn (field) Rice, Wheat,(grain)	10,000-16,000,Cotton, Sugar beet Barley (grains)
Sample No.dry	8,24	7,9,13,14,15,16,17,18,19.25	1,2,3,4,5,6,10,11,20,21,22,23,26,27,28,29,30
Sample No.wet	8,24	6,9,13,14,15,16,17,18,19,21,25	1,2,3,4,5,10,20,,22,23,26,27,28,29,30

Water Quality for Irrigation Purposes:

Irrigation waters pumped from wells contain considerable chemical constituents derived from natural environment and man activities that may reduce crop yield and deteriorate soil fertility (Jalali, 2009). The application of irrigation water to the soil introduces salts into the root zone. Plant roots take in water but absorb very little salt from the soil solution. Similarly, water evaporates from the soil surface but salts remain behind. The processes result in a gradual accumulation of salts in the root zone affecting the plants by creating salinity hazard, water deficiency and toxicity (Jalali, 2011a). Knowledge of irrigation water quality is critical to understanding what management changes are necessary for long-term productivity (Jalali, 2011b). Besides these, irrigated agricultural crops need very good quality water. Hence to cope with such problems, it is necessary to have detailed information concerning the quality of irrigation water and its effect on soils and crops. Hence an attempt has been made in the present study to demarcate the quality of irrigation water. Good quality irrigation water is essential for proper growth of crop plants. Groundwater suitability for irrigation purpose in this study was assessed using various irrigation parameters. The irrigation parameters are Sodium Adsorption Ratio (SAR), Soluble Sodium Percentage **(**SSP), Magnesium Ratio (MAR), Kelly's Ratio (KR) and Permeability Index (PI). The results of these irrigation parameters in both seasons are presented in **Table 13** and **Table 14**. Due to the fact that saline water will produce an alkali soil and irrigation with Na^{+} enriched water results in ion exchange reactions such as uptake of Na^{+} release of Ca^{+2} and Mg^{+2} this causes soil aggregates to disperse and reduces its permeability therefore the tendency of sodium to increase its proportion on the cation exchange sites at the expense of other types of cationic (primarily calcium and magnesium) is estimated by the sodium adsorption ratio (SAR) this ratio has been used widely in the assessment of surface and groundwater (Miller and Gardiner, 2007 ;Tijani ,1994 ;Khodapanah et al. ,2009 and sadashivaiah et al ., 2008). The Sodium Adsorption Ratio is calculated according to the equation and the usage of the different water types included in this study for irrigation is mentioned in Table (9):

$$SAR = \frac{Na^{+}}{\sqrt{\left(\frac{Ca^{2+} + Mg^{2+}}{2}\right)}}$$

Table (9) SAR hazard of irrigation water

Hazard	SAR	Notes	Dry sample	Wet sample
none	<3.0	No restriction on the use of recycled water	1,2,3,4,5,6,7,8,12,15,24,26,28	-
Slight to moderate	3.0-9.0	From 3 to 6 :care should be taken with sensitive crops	9,10,11,13,14,16,17,18,19,21,23,25 ,27,29,30	8,24
		From 6 to 8:gypsum should be used. to be used with insensitive crops	20,22	17
		From 8 to 9 :soil should be sampled and tested every 1 or 2 years to determine whether the water is causing sodium increase	-	16
acute	>9.0	Severe damage .Unsuitable	-	1,2,3,4,5,6,9,10,12,13,14, 18,19,20,21,22,23,25,26 ,27,28,29,30

Permeability Index (PI):

The PI values also indicate the suitability of groundwater for irrigation purpose. The influencing constituents for PI values are total dissolved solid, Sodium bicarbonate and the soil type. It is defined as. follows (Ragunath,1987): $PI = \frac{Na^{+} + \sqrt{HCO_3^{-}} \times 100}{Ca^{2+} + Mg^{2+} + Na^{+}}$ where the concentrations are in meq/l.

From **Table 13** and **Table 14**, the PI values in dry season fall under "Good to permissible and Doubtful to unsuitable while in wet seasons fall under Good to permissible class for irrigation purpose. The classification of water samples with respect to PI value is shown in **Table 10**

Table 10. Quality of irrigation water based on PI values.

Water class	PI values	during Dry sample	during Wet sample
Excellent	>75	--------------------	--------------------------
Good to permissible	75 - 25	**19,20,22,23,27**	**1-28**
Doubtful to unsuitable	<25	**1-18,21,24-26,28-30**	------------

Soluble Sodium Percentage (SSP):

This is an important factor for studying sodium hazards. Sodium has the potential of reacting with soil thereby reducing its permeability and supports little or no plant growth (Joshi et al.,2009). It is defined (Todd, 1995)as: $SSP = \frac{(Na^{+} + K^{+}) \times 100}{Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}}$ Where the concentrations are in meq/l. Based on SSP values, 100% of analyzed water samples belong to "Excellent" class during both seasons (**Table 11**). High SSP values may mean stunted plant growth and reduce soil permeability (Joshi et al.,2009).

Table 11. Quality of groundwater based on SSP values

Water class	SSP values	Dry sample	Wet sample
Excellent	< 60	**All samples**	**All samples**
Good to permissible	60 - 75	--------	--------
Doubtful to unsuitable	>75	---------	---------

Kelly's Ratio: Kelly's ratio is calculated by the numerical formula (Kelly, 1963) : $KR = \frac{Na^{+}}{Ca^{2+} + Mg^{2+}}$

KR values of 1 or < 1 is an indication of good quality water for irrigation purpose while KR of > 1 is unsuitable for agricultural purpose due to alkali hazard (Ragunath,1987). Based on this classification, the KR values of groundwater samples in dry season shows that 100% belong to "Good" class for irrigation purpose. During Wet season, 75% of analyzed groundwater samples belong to "Good" class while only 25% belongs to "Unsuitable" class for irrigation use (**Table 12**)

Table 12. Quality of groundwater based on KR values

Range of KR	Water class	Dry sample	Wet sample
<1 or 1	Good	All samples	3,4,5,6,8, 9,12,14-25,29,30
>1	Unsuitable		1,2,10,13,26,27,28

Magnesium ratio (MAR):

The Ca^{+2} and Mg^{+2} ions maintain a state of equilibrium in most groundwater (Hem, 1985). In equilibrium, Mg^{+2} in water affects the soil by making it alkaline and results in decrease of crop yield (Kumar et al., 2007a,b). The measure of the effect of magnesium in irrigated water is expressed as the magnesium ratio (Table 13 and14). Paliwal (1972) developed an index for calculating the magnesium hazard. MR is calculated using the formula: $MAR = \frac{Mg^{2+} \times 100}{Ca^{2+} + Mg^{2+}}$

The MR values range from 34 to 65.7 and 25.4 to 67.1 mg l^{-1} during dry and wet seasons respectively. During dry 50% of samples and 96.42% during wet fall above the permissible limit of 50 mg/ l indicating the unfavorable effect on crop yield and increase in soil alkalinity. Continuous use of water with high magnesium content will adversely affect crop yield and therefore suggests quick intervention (Paliwal, 1972).

Industrial Purpose:

The quality of water required by industries is highly variable depending on the type of industries and stages. However, two important properties of water such as corrosion and incrustation need to be taken into account to find out their suitability in industries. The corrosion is a chemical action of dissolution of metals, while the incrustation is the precipitation of calcium carbonate or silicate on metals. The Corrosive ratio (C.R.) is defined by the formula (Rhyzner, 1944) as given below. C.R.={(Cl-/35.5)+2($SO4^{2-}$/96)}/ {2($HCO3^{-}$+$CO3^{2-}$) / 100}. If the CR is < 1, then the water is non–corrosive and if the CR > 1, then the water is corrosive (Regarajan and Balasubramaniam, 1990).Where all ionic concentration are expressed in mg/l. The corrosive ratio of the water samples of the study area varies from 15.98 to 58.32 in the dry season and 27.34 to 65.51 in wet season. In the study area, 100 % of the all samples during both seasons have corrosive values more than 1, indicating their unsuitability for industrial purpose. The corrosive nature of the groundwater can be found from a pH value less than 7. It is found that 100% of the all samples in both seasons are non-corrosive .table(13,14)

Table 13. Indices for water quality criteria for irrigation and industrial use of ground water samples in and around

No. well	Dry season										
	SSP	SAR	MAR	KR	CR	P.I	CAI	EC	TDS	TH	PH	Depth
١	18.70	٢.٢	٤٦.٤	٠.١٨٥	26.9	17.39	0.767	10430	6675.2	1800	7.81	15
٢	12.47	1.93	٤٧.٩	٠.١٢٥	36.96	12.31	0.839	13980	8947.2	3000	7.62	20
٣	7.92	١.٢٧	٤٥.٩	٠.٠٧٢	42.42	7.8	0.899	14550	9312	3700	7.38	15
٤	5.98	٠.٨١٥	٤٨.٤	٠.٠٤٤	36.96	5.3	0.907	13020	8332.8	4300	7.43	15
٥	15.98	٢.٢٧	٥٣.٩	٠.١٧٣	20.59	16.57	0.789	10600	6784	2500	7.77	15
٦	14.99	٢.١٩	٦٥.٧	٠.١٦	38.54	15.05	0.768	10610	6790.4	3200	7.74	19.5
٧	15.59	٢.٢٨	٤٩	٠.١٧٣	32.96	16.19	0.739	8460	5414.4	2300	7.69	19
٨	14.36	٢.٣١	٥٤.٧	٠.١٥٩	38.71	14.85	0.74	5810	3718.4	3100	7.51	19.5
٩	21.19	٣.١	٥٣.٥	٠.٢٥٦	26.78	22.01	0.629	7990	5113.6	2100	7.66	24
١٠	20.76	٣.٥١	٥٤.٣	٠.٢٥٣	19.66	21.88	0.645	10530	6739.2	2800	7.83	19
١١	18.74	٤.١٧	٤٥.٥	٠.٢٢٠	73.78	18.33	0.774	12460	7974.4	3000	7.81	15
١٢	17.91	٢.٩٤	٥٩.٥	٠.٢٠٩	47.45	18.33	0.691	9970	6380.8	3100	7.84	18
١٣	19.77	٣.٥٣	٣٦.٥	٠.٢٣٨	36.55	20.39	0.736	9960	6374.4	2350	8.16	12
١٤	19.97	٣.٥٩	٤١.٨	٠.٢٤٣	41.87	20.64	0.721	8980	5747.2	2550	7.96	30
١٥	11.31	١.٩٣	٦٣.٤	٠.١٢٤	58.32	12	0.851	9690	6201.6	4000	7.83	28
١٦	22.33	٣.٩٦	٦٠.٣	٠.٢٧٩	31.94	23.05	0.616	7290	4665.6	3200	7.85	28
١٧	19.09	٣.٤٣	٥٢.٢	٠.٢٢٤	37.18	19.4	0.56	6750	4320	3200	7.59	7
١٨	21.31	٤.٣٤	٤٦.٨	٠.٢٦٥	45.62	21.81	0.534	8460	5414.4	3300	7.53	11
١٩	29.77	٥.٧٢	٥٧.٨	٠.٤١٦	23.77	30.78	0.281	9860	6310.4	2900	7.41	24
٢٠	31.52	٦.١١	٦٢.٧	٠.٤٥٣	22.94	32.57	0.121	11210	7174.4	3000	7.63	8.5
٢١	21.24	٣.٩٣	٤٠.١	٠.٢٥٧	21.93	21.93	0.591	10020	6412.8	2500	7.94	9
٢٢	31.88	٦.٢٦	٥٧.٦	٠.٤٥٥	15.98	32.94	0.163	12960	8294.4	2900	7.54	9
٢٣	25.23	٤.٥٤	٥٧.٤	٠.٣٢٤	24.79	25.84	0.295	10550	6752	3000	7.38	11
٢٤	14.42	٢.٦١	٣٤.١	٠.١٦٥	34.38	15.37	0.727	4980	3187.2	2300	7.58	9
٢٥	16.61	٣.٠٦	٣٤	٠.١٩٢	40.43	17.14	0.698	6640	4249.6	2300	7.77	5
٢٦	14.82	٢.٤٦	٤٠.٥	٠.١٦١	27.18	15.25	0.67	10190	6521.6	2500	7.57	8
٢٧	24.83	٤.٧٦	٦٠.٣	٠.٣١٩	29.76	25.34	0.338	11140	7129.6	3500	7.46	6
٢٨	15.51	٢.٦٦	٤٩.٤	٠.١٧١	28.42	15.93	0.604	10520	6732.8	3100	7.78	26
٢٩	24.	٤.٥٢	٤٧.٨	٠.٣٠٣	32.94	24.39	0.469	10980	7027.2	2900	7.52	24
٣٠	18.02	٣.٥٥	٥٠.٣	٠.٢١٠	23.14	18.64	0.564	16050	10272	3800	7.33	15

Table 14. Indices for water quality criteria for irrigation and industrial use of ground water samples in and around

No.well	Wet season											
	SSP	SAR	MAR	KR	CR	P.I	CAI	EC	TDS	TH	PH	Depth
1	57.61	14.7	٦٧.١	1.330	31.98	58.42	0.072	10310	6598.4	2100	7.51	15
٢	54.81	15.8	54.1	1.199	35.8	55.57	-0.003	13790	8825.6	2500	7.15	20
٣	39.88	11.2	56.1	0.655	64.89	40.3	0.339	14380	9203.2	3500	7.09	15
٤	38.76	9.88	57	0.623	54.37	39.24	0.31	11990	7673.6	3400	7.33	15
٥	42.98	10.6	60.5	0.742	52.98	43.51	0.275	10570	6764.8	3200	7.37	15
٦	41.21	9.4	57	0.687	42.04	41.84	0.068	8500	5440	2800	7.5	19.5
٨	30.23	5.52	57.1	0.426	54.64	30.97	-0.036	5680	3635.2	2500	7.51	19.5
٩	42.78	9.7	54.1	0.734	33.7	43.58	0.362	7900	5056	2500	7.39	24
١٠	50.38	13.4	55.1	1.006	47.29	51.11	0.247	10890	6969.6	2600	7.13	19
١٢	33.39	9.24	25.4	0.497	60.52	33.88	0.42	10880	6963.2	1799	7.36	18
١٣	51.63	13.2	53.5	1.057	35.23	52.57	0.254	9700	6208	2200	7.52	12
١٤	43.29	9.95	54.1	0.753	40.01	44.08	0.271	8930	5715.2	2500	7.37	30
١٥	44.17	10.9	58.9	0.782	51.85	44.82	0.216	9840	6297.6	3000	7.48	28
١٦	42.07	8.92	53.5	0.716	34.53	43.02	0.347	7410	4742.4	2200	7.14	28
١٧	37.41	7.18	56.2	0.576	27.34	38.07	0.38	6530	4179.2	2300	7.41	7
١٨	42.50	9.72	59.8	0.725	38.57	43.2	0.304	9090	5817.6	2800	7.53	11
١٩	45.29	10.4	58.4	0.817	32.96	46.23	0.351	8620	5516.8	2500	7.45	24
٢٠	45.94	11.5	61.6	0.842	38.49	46.79	0.284	10660	6822.4	3000	7.29	8.5
٢١	44.73	10.5	54.1	0.796	33.35	45.56	0.296	9450	6048	2500	7.14	9
٢٢	48.66	13.3	60.5	0.933	48.89	49.19	0.249	13220	8460.8	3200	7.34	9
٢٣	44.23	11.2	61.3	0.781	51.73	44.76	0.351	11750	7520	3300	7.26	11
٢٤	30.48	5.24	56.2	0.420	24.34	31.29	0.464	5800	3712	2300	7.8	9
٢٥	41.71	9.23	50.6	0.707	65.51	42.34	0.31	7910	5062.4	2300	8.02	5
٢٦	51.33	13.4	55.8	1.045	37.27	52.24	0.213	10350	6624	2400	7.58	8
٢٧	54.25	14.9	55.8	1.170	39.55	54.97	0.175	11040	7065.6	2400	7.46	6
٢٨	57.37	15.6	55.8	1.337	39.36	58.34	0.001	10610	6790.4	2000	7.61	26
٢٩	41.36	11	61.6	0.696	47.41	41.93	0.303	12010	7686.4	4000	7.55	24
٣٠	46.68	13.1	58.2	0.863	35.49	47.35	0.313	13780	8819.2	3500	7.21	15

Conclusions and Recommendation

The quality assessment of groundwater in Safwan -Al Zubair area shows it is slightly alkaline and slightly brackish to brackish water during in both season. and with respect to the amount of total hardness, the water is very hard. Groundwater is contaminated with Ca ,Na, K and Mg . The main causes of this contamination are the agricultural activities(fertilizers, pesticides, and herbicides), the saline water intrusion from the lower part of aquifer, and the saline wastewater of desalination plants, in addition to the calcareous and evaporates materials that are contained in the Dibdibba formation.

Groundwater is contaminated with Cl and SO4. The most prevalent causes of Cl contamination are: saline water intrusion, wastewater, sewage, and agricultural activities. Regarding SO4, agricultural activities, wastewater, and evaporates materials represents the main causes of groundwater contamination. The human activities especially agriculture, sewage, garbage, and desalination plants waste water, represent the main sources of the contamination with contribution from the natural sources in the study area.

The factors (rNa/rCl), rMg/rCl, rk/rCl ,**rCa/rCl** , rSO_4/rCl ,HCO_3/CL and Cl-Na/Mg are used to determinate the origin of this groundwater. After comparing the values of these factors obtained in the studied area with standard reference values, it appears that the origin of the groundwater is divided into two types, marine and meteoric origin, and also shows a gradual change from deep groundwater of marine origin to shallow one of meteoric origin.

In the dry period, the predominant water type is NaCl (85.68%), then Na_2SO_4 (3.57%), while in the wet period, the predominant water type is $CaCl_2$(36.63%) and then $MgCl_2$(26.64%), $MgSO_4$(23.31%) $CaSO_4$ (13.321%).

The order of cationic abundance is Ca > Mg > Na+K in the dry season and Na + K > Mg > Ca the trend changed as in the wet season due to the except some samples where Ca^{+2} replaces Na^{+} in the wet season by cationic exchange reactions.
Chloroalkaline Indices 1, 2 calculations shows that 7.1% of the groundwater sample is negative and 99.55% positive ratios. The positive values indicate absence of base-exchange reaction.
Higher TDS was noticed during dry season period. Higher log pCO2 values ranges form-3.013 to -1.896 in both the seasons and suggest that the additional CO2 has been acquired from the soils during the development of infiltration towards the zone of saturation.
Hydrogeochemical modeling indicate the saturation index of carbonate minerals are following in the order: SI Calcite > SI Aragonite in both seasons .The SI of groundwater with deference of carbonate minerals indicate that the supersaturated in both season indicating decay of organic matter and root respiration as sources.
The comparison of analyzed data with WHO (2008) and ISI (2009) indicate that groundwater samples of the area are unsuitable for drinking. because of high contents of TDS, Na^{+}, and Cl^{-} and hardness.
Finally, the groundwater is not recommended for drinking purpose, while For irrigation purpose, groundwater was unsuitable, but according to Tood (2007) classification, the groundwater of the study area is suitable to irrigation. With the high permeable soil of Safwan -Al Zubair and choosing high salinity resistant crops, groundwater can be used successfully in irrigation.
Based on the water quality parameters analyzed like SAR, SSP, MAR, PI and KR the suitability of groundwater samples for irrigation waters classified based on SAR has indicated that 43% of samples belong to the excellent, 56% samples good in dry season and 17% samples good ,remaining samples belong to doubtful category in wet season.
Base on the classification of irrigation water according to the SSP values, all of groundwater samples belongs to the excellent category in both season . According to PI values, the groundwater of in the study area can be designated as class II (25–75%) in wet season and class II(25–75%) and class III<25 ,that shows the groundwater in study area is suitable for irrigation purposes in wet season, while 76% of water samples unsuitable in dry season. Assessment Based on this classification, the KR values of groundwater samples in dry season shows that 100% belong to “Good” class for irrigation purpose. During Wet season, 75% of analyzed groundwater samples belong to “Good” class while only 25% belongs to “Unsuitable” class for irrigation useThe MR values range from 34 to 65.7 and 25.4 to 67.1 mg l^{-1} during dry and wet seasons respectively. During dry 50% of samples and 96.42% during wet fall above the permissible limit of 50 mg/ l indicating the unfavorable effect on crop yield and increase in soil alkalinityThe calculated values of corrosivity ratio suggest that 100% samples are corrosive in nature and need non-corrosive pipe for transporting and lifting of groundwater. Considering corrosivity ratio, the ground water samples are Unsuitable for industrial use

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