Engineering and Technology Journal
Journal homepage: https://etj.uotechnology.edu.iq

Hydrochemical and Environmental Assessment of Groundwater in Al-Yusufiyah District South-west Baghdad, Iraq

Rafal Abdulrazzaq*, **Tariq Abed Hussain, Ghufran F. Jumaah**

Civil Engineering Dept, University of Technology-Iraq, Alsina'a Street, 10066 Baghdad, Iraq.
*Corresponding author Email: Rafalrazaq9@gmail.com

HIGHLIGHTS

- Most wells in the study area have water types of NaCl and $MgSO_4$, and the other wells are $CaCl_2$ and Na_2SO_4.
- Groundwater in Al-Yusuifyia district is not suitable for drinking due to the high concentration of Cl, SO_4, HCO_3, and TDS, ECbecause they are exceeded the standard limit of WHO.
- For irrigation purposes, the well water is considered good and permissible.

ARTICLE INFO

Handling editor: Qusay F. Alsalhy

Keywords: Hydrochemical Assessment; Groundwater; Environment; Yusufiyah Area

ABSTRACT

Groundwater in Yusufiyah represents the main water source for drinking and irrigation purposes in the dry season, so this research was conducted to assess and evaluate the hydrochemistry of groundwater in this area. (15) wells were selected for sampling in this area with depth ranges between 10-20 meters. , Groundwater generally flows from east to west and from northeast to southwest.Physical parameters for water samples were measured included temperature, pH, electrical conductivity (EC), and total dissolved solids (TDS),where the chemical parameters included major cations (Ca^{+2}, Mg^{+2}, Na^{+2}, and K+) and major anions (NO_3^{-1}, SO_4^{-2},Cl^-, and HCO_3^-). The results indicated that groundwater in the study area isnot suitable for human drinking due to high concentrations in(Cl=435 ppm), (SO_4^{-2} =769 ppm), (HCO^{-3}=280 ppm),(TDS=2375 ppm), and (EC=2899μc). These values exceeded the standard limits of WHO. On the other hand, results show that this water was suitable for irrigation (good and Permissible except for well no.1,8,12,13, which wasnot suitable for all irrigation crops due to an increase in (SAR, Na) to the Don classification 1995.

1. Introduction

Water is the basis for the existence of living organisms. And the importance of its availability and quality is constantly increasing. Groundwater is the main source of drinking and irrigation water and the basis of human stability in various parts of the earth, especially in areas where surface water sources are not available [1]. Most researchers agree that major sources of groundwater pollution are municipal and industrial Wastewater, leachate from damped solid waste and agricultural run-off [2].which are mostly refer to human activities demonstrated by using septic tank , un controlled landfills and network systems and using of fertilizers and pesticides. most of these sources are rich with deferent viruses ,bacteria and high concentration of nitrogen and chloride compounds as well as they contribute to increase the concentration of organic material .Furthermore the evaluation process of groundwater and identify it validity for drinking and irrigation is complex process because it is varies widely from region to region depending on the type of aquifer and soil.

The quality of groundwater in Iraq has undergone a significant deterioration in its properties as a result of the indiscriminate withdrawal of that water, due to the lack of access to drinking water networks in some areas to meet the drinking and irrigation requirements, in addition to the lack of sewage networks that prompted the population to drain sewage waste into septic basins, which greatly affected the In groundwater variables represented by the rise of salts and organic and biological groundwater pollutants.

Therefore it is important to study the groundwater resources to maintain theiroptimum investment [3]. The Yusufiyah district, located in the southwest of Baghdad, lies within importantagriculturally and economically areas.

This research aims to assess the validity of well water in Al- Yusufiyah district for drinking and irrigation purposes.

1.1 Study area

Al-Yusufiyah city is located southwest of Baghdad located between latitudes (33° 13′ 58" - 33° 01′ 15") and longitudes (44° 08′ 52" -44° 08′ 28") and covers an area of about 805,6 km² as shown in Figure 1.

http://doi.org/10.30684/etj.v40i3.2045
Received 9 March 2021; Accepted 1 September 2021; Available online 25 March 2022
2412-0758/University of Technology-Iraq, Baghdad, Iraq

.

1.2 Materials and method

Fifteen wells were selected in this reign for collecting water samples, as shown in Figure 2. First, the coordinates for each sample (Longitude, Latitude, and Elevation) were accurately determined using a GPS (Global Positioning System). Then, the acidity (pH), electrical conductivity (EC), and total dissolved salt (TDS) and (TC°) temperature of the water samples were measured in the field. On the other hand, the cations and anions were measured and performed in the Water Research Center of Ministry of Science and Technology; according to standard methods (Lind, 1979; WHO, 2006; APHA, 2005, APHA, 2012).

1.3 pH Values

A reliable pH measurement is one of the most important field parameters. pH is measured directly in the field. pH values for well water samples ranged between (7.09 -7.62) with an average of 7.35. The pH values of water samples are of low alkalinity.

1.4 Total Dissolved Solids (TDS)

Water's palatability at less than 600 ppm is usually considered strong with absolute dissolving solid levels. In contrast, the drinking water at TDS levels is considerably less palatable than approximately (1000 ppm) [2]. Results of TDS were ranged between (950-3800) ppm in groundwater samples to an average of (2375 ppm), and this value exceeds the limit of WHO 2017.IQS2009. This increase is attributed to the use of septic tanks, which are the only way of discharging wastewater in the research area, and fertilizers and pesticides, as shown in Figure 2A.

1.5 Electrical Conductivity (EC)

EC readings ranged from (1268µs/cm) to (4530 µs/cm) while the average reading of 2899 µs/cm. The water sample is categorized under [3] as “Excessively mineralized water”. Figure 2-B shows the distribution of the (EC) concentrations of the wells in the study area.

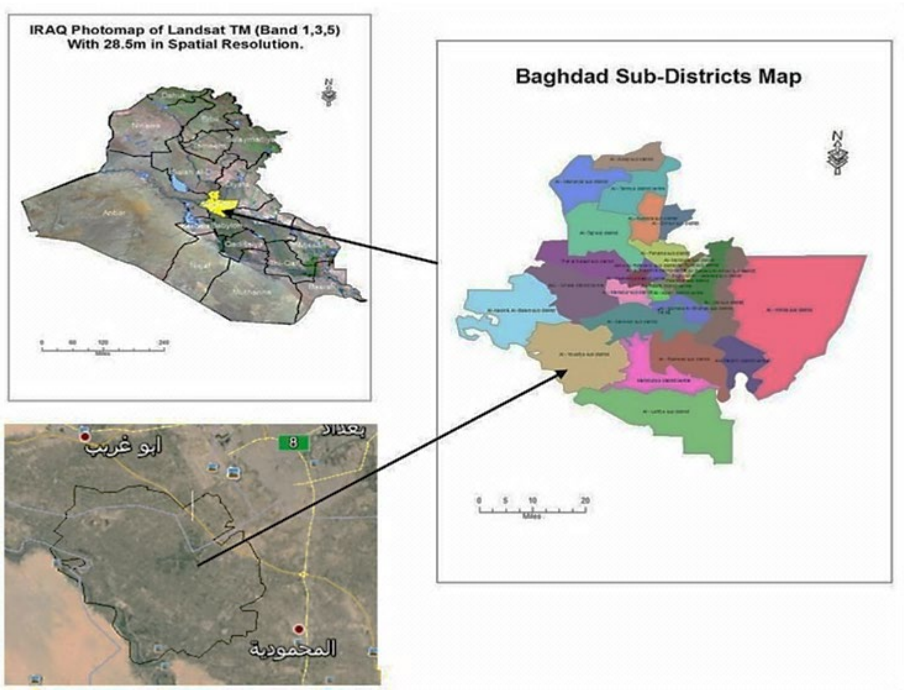


Figure 1: Location of the study area for AL-Yusufiyah

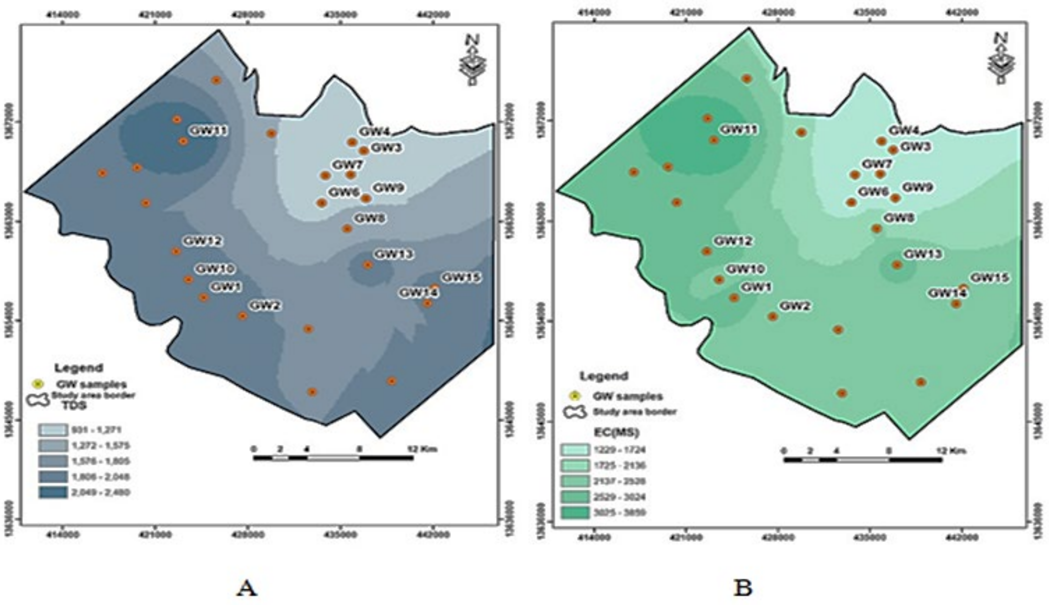


Figure 2: spatial distribution of concentrations in the study area (A) TDS (B) EC value

2. Chemical properties

Material rock decomposition into the groundwater and active potential evapotranspiration were to blame for the elevated concentrations of chemical contaminants in the groundwater [4]. This research is based on laboratory results of major cations and anions.

2.1 Cations

Calcium (Ca^{+2}) concentrations were ranged between (58-270) ppm with an average value of (146) ppm, as illustrated in Table 1 and Figure 3- C.

Magnesium (Mg^{+2})concentrations ranged from 31 to 166 ppm with an average of approximately 98.5 ppm, as shown in Figure 3-D and Table 1.

Potassium (K^{+}) concentrations are summarized in Table 1 and indicate that the potassium ion concentration ranges from (5-536) ppm with an average value of 270.5 ppm. Figure 4-E shows the distribution of the wells' potassium ion concentrations (K+1) in the studied area.

Sodium (Na^{+1}) results show that water samples show varying Na^{+1} concentrations from (88-354) ppm with an average value of 171 ppm Table 1 and Figure 4-F show the distribution of the concentrations of the Sodium Ion (Na^{+1}) of the wells in the study area.

2.2 Anions

1. Chloride ion (Cl^{-}): - the samples for groundwater are between (154-716ppm), with an average of about 435 ppm, then increasing the chlorine concentration due to the use of organic fertilizers and human activities in the study area. And this result exceeds the limits in the [5] and [2] Table 1. Figure (5-G) shows the distribution of the Chloride ion (Cl-) concentrations of the wells in the study area.
2. Sulfate ions (SO_4^{-2}):-, groundwater samples indicate the difference in the concentration of (SO_4^{-2}) between (242 – 1296) ppm and the average of (769 ppm) High concentration of sulfate ion in the area means increased concentration of anaerobic bacteria., Table 1, Figure (6-J) shows the distribution of the concentrations of the sulfate ions (SO_4^{-2}) wells in the study area.
3. Bicarbonate (HCO_3-):-The amount of bicarbonate in groundwater must not exceed (200 ppm) [5] and [2]. In the analysis, groundwater samples demonstrated that (HCO^{-}_3) concentration ranges from (51-509) (ppm) with an average of (280 ppm) ǀ].Table1, Figure (5-H) shows the distribution of Bicarbonate (HCO_3^{-}) concentrations in the wells in the study area.
4. Nitrate NO_3^{-2}:- Nitrate has a major inorganic chemical influence on plant growth and can threaten drinking water and supplies if Nitrate levels are (10ppm) or more [6]. In the region of research, results of groundwater indicate that (NO_3^{-2}) concentration ranges between (1 -28.8 ppm) with an average of (14.9) ppm. These increase in the concentration of NO_3^{-2} because of the use of fertilizer. On the other hand, the use of the septic tank as deranging wastewater in the region [7]. Table 1 and Figure 6-I show the Nitrate (NO_3^{-2}) concentrations of the wells in the study area.

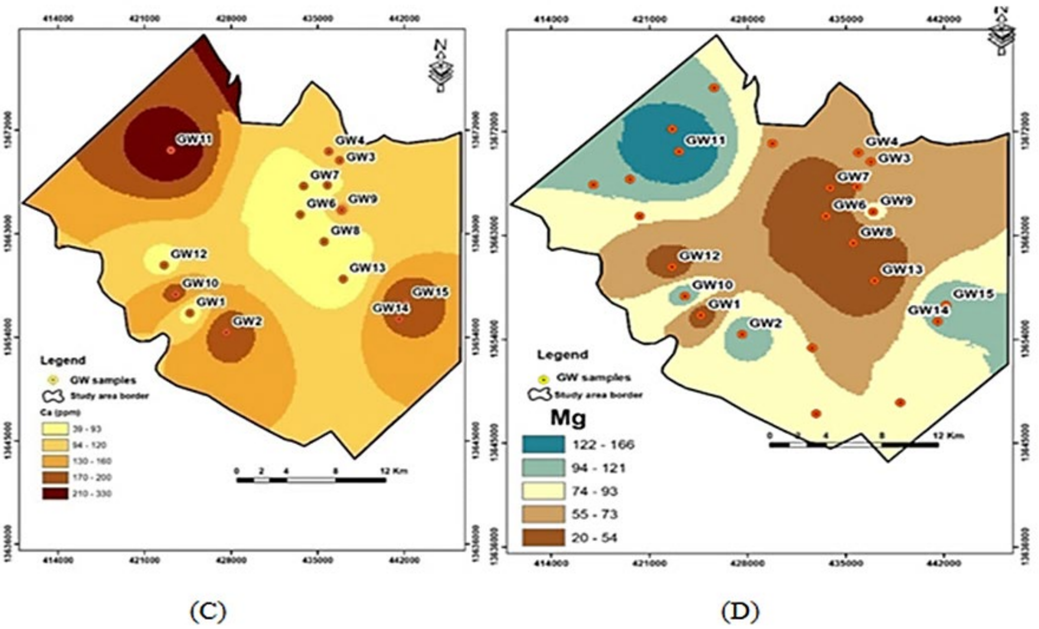


Figure 3: spatial distribution for concentrations in research area (C) Ca^{+2} (D) Mg^{+2}

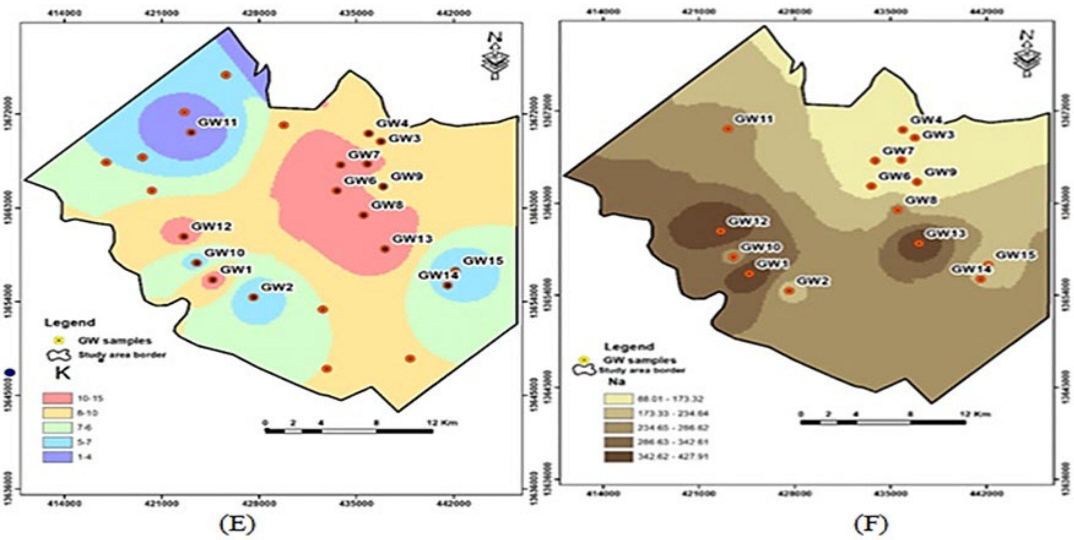


Figure 4: Spatial distribution of concentration in the study area (E) K^{+} (F) Na^{+2}

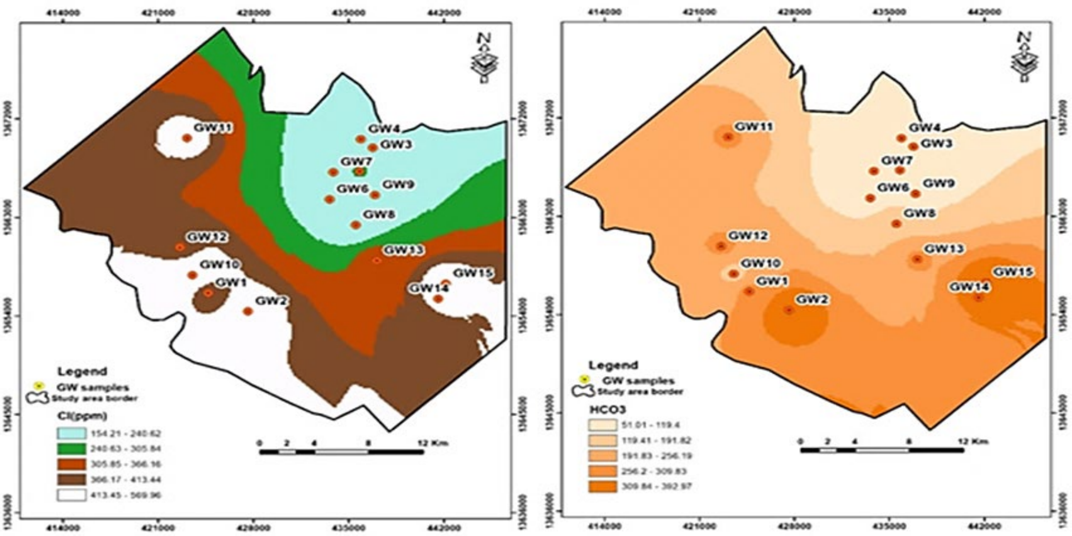


Figure 5: spatial distribution of concentration in the study area (G) CL^{-} (H) HCO^{-}_{3}

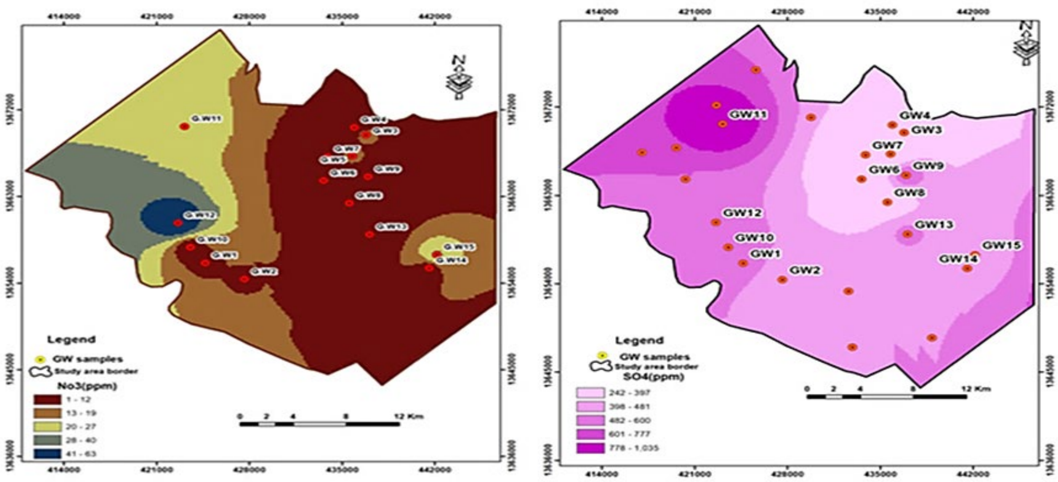


Figure 6: Spatial distribution of concentration in the study area (I) NO^{-2}_3 (J)SO_4^{-2}

Table 1: Major cations and anions in (ppm) units of wells water in the study area

Sample	ppm									
	Ca^{+2}	*Mg^{+2}*	*Na^{+}*	*K^{+}*	*Sum. Cat.*	*Cl^{-}*	*SO_4^{-2}*	*HCO_3^{-}*	*NO_3^{-}*	*Sum. Ani.*
1	71	36	424	12.1	543.1	362	510	270	9.4	1151.4
2	195	112	214	3.8	524.8	471	420	393	10.46	1294.5
3	100	70	88	10	268	190	300	50	5.6	545.6
4	108	68	88	5	269	182	379	51	4.06	616.06
5	82	54	132	4.1	272.1	254	245	64	14.02	477.02
6	58	31	153	1.4	243.4	208	242	72	8.6	530.6
7	58	31	153	1.4	243.4	208	242	72	6.2	528.2
8	39	20	245	8.5	312.5	159	306	193	4.5	662.5
9	130	83	94	9.4	401	154	582	62	1.05	799.05
10	181	116	254	1.54	616.4	570	519	164	2.8	1255.8
11	270	166	248	2.48	708.8	445	1035	265	25.18	1770.18
12	71	36	428	4.28	577.8	362	510	270	63.5	1205.5
13	75	36	424	1.5	550	300	510	170	1	981
14	332	157	332	5.36	874.6	716	1296	509	6.4	2527.4
15					542.4	471	420	393	28.8	1312.8

Table 2: Chemical analysis in (epm) units for wells in the area of study

Sample	epm										
	Ca^{+2}	*Mg^{+2}*	*Na^{+}*	*K^{+}*	*Sum.Cat*	*Cl-*	*SO_4^{2}*	*HCO_3^{-}*	*NO_3^{-}*	*Sum. Ani.*	*Accuracy A%*
1	3.55	2.95	18.43	0.31	25.24	10.20	10.63	4.43	0.08	25.34	99.82
2	9.75	9.18	9.3	0.097	28.33	13.27	8.75	6.44	0.10	28.56	99.42
3	5	5.83	3.82	0.25	14.90	5.35	6.25	0.82	0.09	12.51	91.3
4	5.4	5.57	3.82	0.13	14.92	5.13	7.90	0.84	0.12	13.99	96.75
5	4.1	4.42	5.61	0.1	14.23	7.15	5.10	1.05	0.11	13.41	97.1
6	2.9	2.58	6.65	0.035	12.17	5.86	5.04	1.18	0.04	12.12	99.84
7	2.9	2.58	6.65	0.035	12.17	5.86	5.04	1.18	0.04	12.12	99.84
8	1.95	1.63	10.65	0.22	14.45	4.48	6.38	3.16	0.08	14.10	98.8
9	6.5	6.80	4.08	0.24	17.62	4.34	12.13	1.02	0.03	17.52	93.92
10	9.05	9.50	11.04	0.04	29.63	16.05	10.81	2.69	0.01	29.56	99.28
11	13.5	13.60	10.78	0.063	37.94	12.54	21.56	4.42	0.02	38.54	99.9
12	3.55	2.950	18.6	0.11	25.21	10.20	10.63	4.43	0.02	25.28	98.2
13	3.75	2.950	18.43	0.04	25.17	8.45	10.63	2.78	0.08	21.94	99.6
14	16.6	12.86	14.4	0.137	44.00	20.17	27.00	8.34	0.06	55.57	89.9
15	9.75	9.18	9.3	0.055	28.29	13.27	8.75	6.44	0.10	28.56	99.62

3. Biological characteristics

1. Dissolved Oxygen (DO):-represented The rule values in groundwater, so the results of water samples ranged between 5.2 ppm and 8.8 ppm with an average value of 7, which they are within the limit (IQS,2009), as shown in Table 3 and spatial distribution for the concentration of DO show in Figure 7-M.
2. Biochemical Oxygen Demand (BOD)groundwater samples showed that the result of BOD ranged between (1.2-10) and with an average value of 5.6, which is greater than (IQS,2009). This indicates that well water in this region is polluted with wastewater due to the absence of a sewage system in this region and the dependence on a septic tank that causes leakage of wastewater and reaches the groundwater. Table 3 and Figure 7-L show the Spatial distribution for study area BOD.
3. Chemical Oxygen Demand (COD):- as a result of increasing in BOD concentrations, the values of COD in this research were between (3.6-30) ppm, with an average value of (18.3) ppm, as elucidated in Figure 7-K and Table 3.

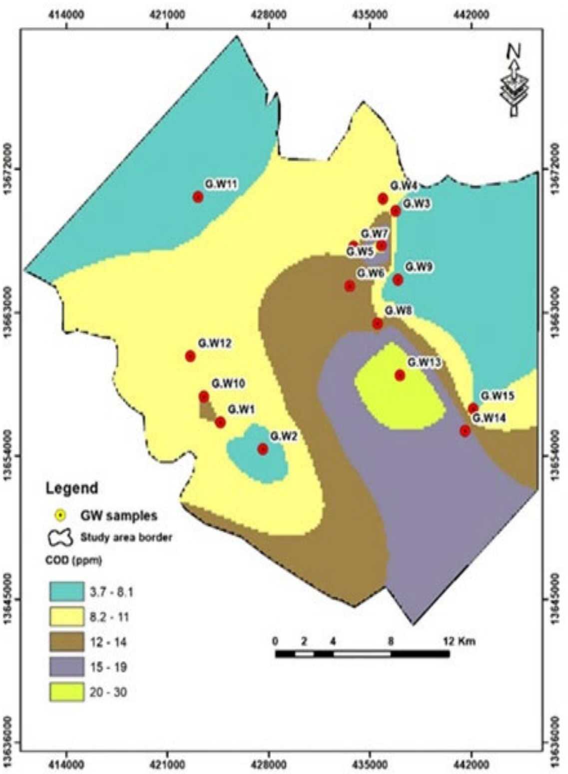
3.1 Hydrochemical Formula and Water Type

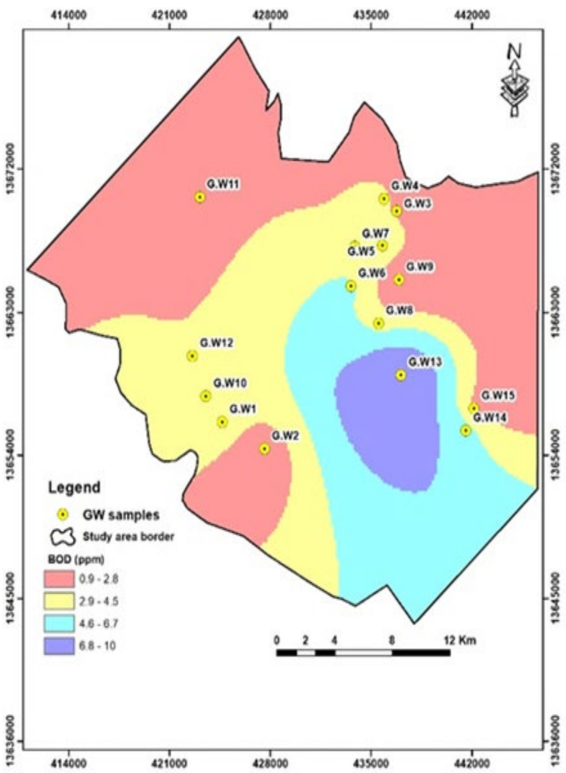
The chemical formula for hydrochemical water depends on the ratio of main cations and anions represented by the (epm %) divided by the supply. The cations are placed at the bottom, and the anions are located at the top. Finally, the TDS value is put into (mg/L) units, and (pH) values are taken from Kurlolov Formula as follows in Table 4: Kurlolov Formula 1

$$\text{TDS (mg/l)} \ \frac{Anions\ (epm\%)\ indecreasingorder}{Cations\ (epm\%)\ indecreasingorder} \quad (1)$$

Table 3: Ranges of Biological characteristics Concentration in groundwater

Parameters	Range	Mean	IQS,2009))
BOD	1.2- 10	5.6	≤ 5
COD	3.6- 30	18.3	-
DO	5.2-8.8	7	8.3





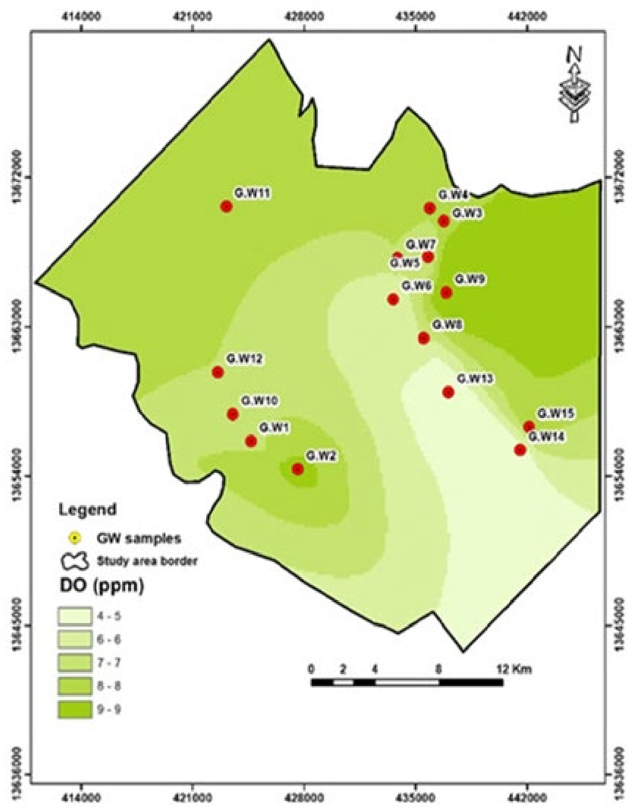


Figure 7: Spatial distribution of concentration in study area (K) COD,(L) BOD (M) DO

3.1.1 Groundwater Classification

Based on chemical proof, the classification of groundwater relies on the purpose of classification and the probability of portraying the classification with various consistency markers, which do not have to reflect the concentration division, and there are many hydrochemical classification methods. Therefore, two classification methods were used in this research, both aimed at distinguishing the consistency of water and its origin.

3.1.2 Piper classification (1944)

Piper's (1944) diagrams are used for the water classification, where three interrelated Figures describe it: two trilinear diagrams pointing to the cations and one diamond that summarizes the diagrams.

Figures 8 and 9 illustrate applying the Piper classification. The groundwater samples are collected within a certain area, with (class e) and (class g) hydro chemical faces. Thus, the geological details are earth alkaline water with substantial elevation of alkaline water with superimposed density of sulphate and chloride, respectively.

3.1.3 Schoeller Classification, 1972

Schoeller suggested (1972) a semi-logarithmic display of the real distribution of the main ion concentration of the water in the descending order of ions, and it is displayed in Table 5 on the vertical axis. The benefit of this scheme is to define the sources of groundwater by noting the slope of the straight line between r (Na + K) and HCO_3 and the presentation of a variety of water analyses and equilibrium between them.

From the above Figures 10 and 11, the water type can be classified as follows:

$NaSO_4$: From the classification of groundwater in the area of study by the Schoeller method, most of the wells are of type B3, Table 5.

3.2 Hydrochemical indicators

The study of hydrochemical indicators is important to delineate the origin of water and the comparison between ions concentration and sea water [8]. The ratio of sodium ion concentration to the chloride ion concentration in the (epm%) unit was used to determine the origin of the water [9] classified water into two groups, depending on the genetic origin: Table 6.

1- Meteoric water, if rNa/rCl > 1.

2- Marine water, if rNa/rCl < 1.

Table 4: The hydrochemical formula for the samples in the study area

Hydrochemical Formula	Water type
W1=TDS(2000)$\frac{\mathbf{SO4(41.95)CL(40.25)HCO3(17.48)}}{\mathbf{Na(73.02)Ca(14.06)Mg(11.69)K(1.23)}}$PH(7.2)	Sodium – HCO_3- – CL^- - Sulphate
W2=TDS(1850)$\frac{\mathbf{Cl(46.46)So4(30.64)HCO3(22.55)}}{\mathbf{Ca(34.54)Na(32.94)Mg(32.52)K(0.34)}}$PH (7.26)	Mg^{+2} – Na – Calcium-HCO^-_3-SO_4-- 2Chloride
W3=TDS(1850)$\frac{SO4(49.96)CL(42.77)HCO3(6.55)}{Mg(39.13)Ca(33.56)Na(25.64)K(1.68)}$pH(7.42)	$Na^{+!}$ –Ca^{+2}Magnesium –CL^- –Sulphate
W4= TDS (1268)$\frac{SO4(56.47)CL(36.67)HCO3(6)}{Mg(37.33)Ca(36.19)Na(25.19)k(0.87)}$PH(7.3)	Na^{+1}-Ca^{+2}- Magnesium- CL^- - Sulphate
W5= TDS (1227) $\frac{Cl(53.32)So4(38.03)HCO3(7.83)}{Na(39.42)Mg(31.06)Ca(28.81)k(0.7)}$pH (7.11)	Ca^{+2}-Mg^{+2}- Sodium- SO^{-2}_4-Chloride
W6= TDS (1570) $\frac{CL(48.35)S04(41.58)HCO3(9.74)}{Na(54.69)Ca(23.85)Mg(21.22)K(0.29)}$pH(7.39)	Mg^{+2}-Ca^{+2}-Sodium – SO^{-2}_4-Chloride
W7= TDS (1570) $\frac{CL(48.35)S04(41.58)HCO3(9.74)}{Na(54.69)Ca(23.85)Mg(21.22)K(0.29)}$pH(7.39)	Mg^{+2}-Ca^{+2}-Sodium- SO^{-2}_4-Chloride
W8= TDS (2190) $\frac{SO4(45.25)CL(31.77)HCO3(22.41)}{Na(73.7)Ca(13.49)Mg(11.28)K(1.52)}$pH (7.7)	Sodium- HCO^-_3 – CL^- - Sulphate
W9= TDS (1457) $\frac{SO4(69.24)CL(24.77)HCO3(5.82)}{Mg(34.38)Ca(32.86)Na(20.63)k(1.36)}$pH(7.7)	Na^{+1}- Ca^{+2}- Magnesium- CL^- - Sulphate
W10= TDS (2310) $\frac{Cl(54.30)SO4(36.57)HCO3(9.1)}{Na(36.8)Mg(31.67)Ca(30.17)k(0.134)}$pH(7.6)	Ca^{+2}-Mg^{+2}- Sodium- SO^{-2}_4-Chloride
W11= TDS (2480) $\frac{SO4(55.94)CL(32.54)HCO3(11.47)}{Mg(35.32)Ca(35.06)Na(27.99)k(0.17)}$pH(7.1)	Na^+- Ca^2- Magnesium- CL^- - Sulphate
W12= TDS(1830)$\frac{SO4(42.05)CL(40.35)HCO3(17.52)}{Na(70.99)Ca(13.55)Mg(11.26)k(0.44)}$pH(7.12)	Sodium-HCO^-_3 – CL^- - Sulphate
W13=TDS (2000)$\frac{SO4(48.45)CL(38.51)HCO3(12.67)}{Na(73.34)Ca(14.92)Mg(11.74)k(0.16)}$pH(7.15)	Ca^{+2}-Sodium - CL^- - Sulphate
W14= TDS(3800)$\frac{SO4(48.59)CL(36.3)HCO3(15.01)}{Ca(36.55)Mg(31.84)Na(28.43)k(0.31)}$pH(7.15)	Na^{+1}-Mg^{+2}-Calcum –HCO^-_3 – CL^-- Sulphate
W15= TDS (1850)$\frac{CL(46.46)SO4(30.64)HCO3(22.55)}{Ca(33.88)Na(32.31)Mg(31.9)K(0.19)}$pH (7.22)	Na^+-Calcume- HCO^-_3- SO^{-2}-$_4$-Chloride

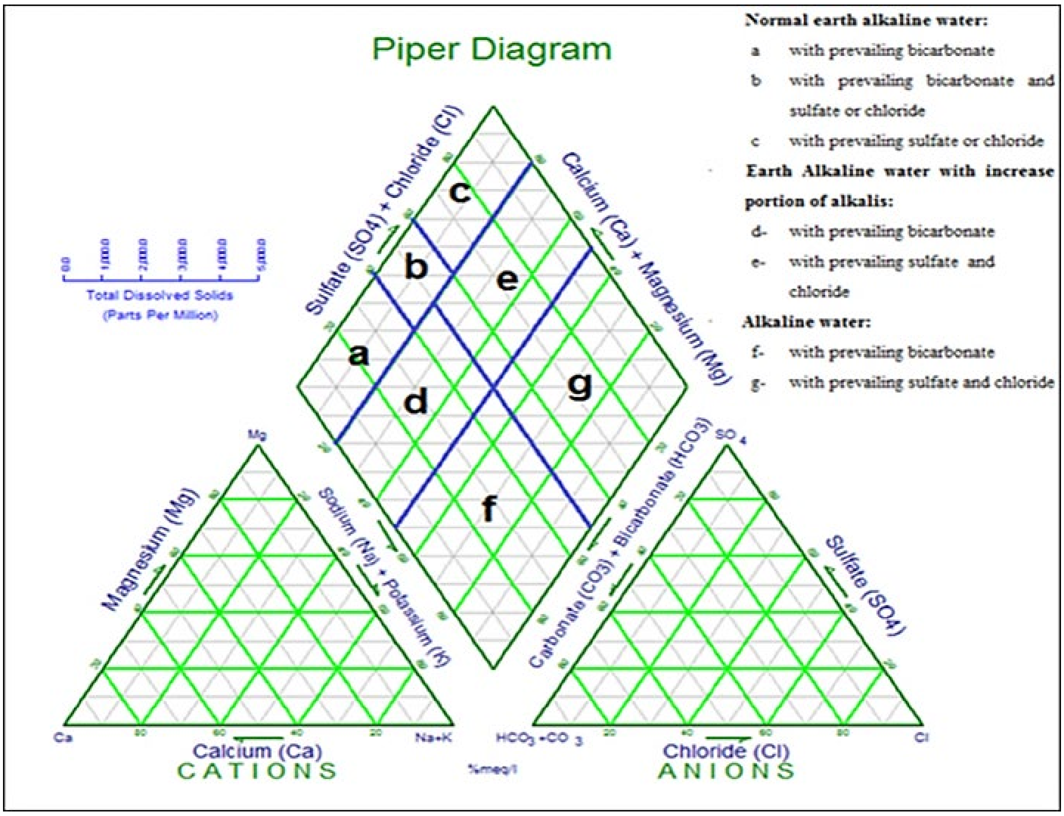


Figure 8: Standards plotting of Piper trilinear diagram, (1944) with the divisions of Langguth, (1966)

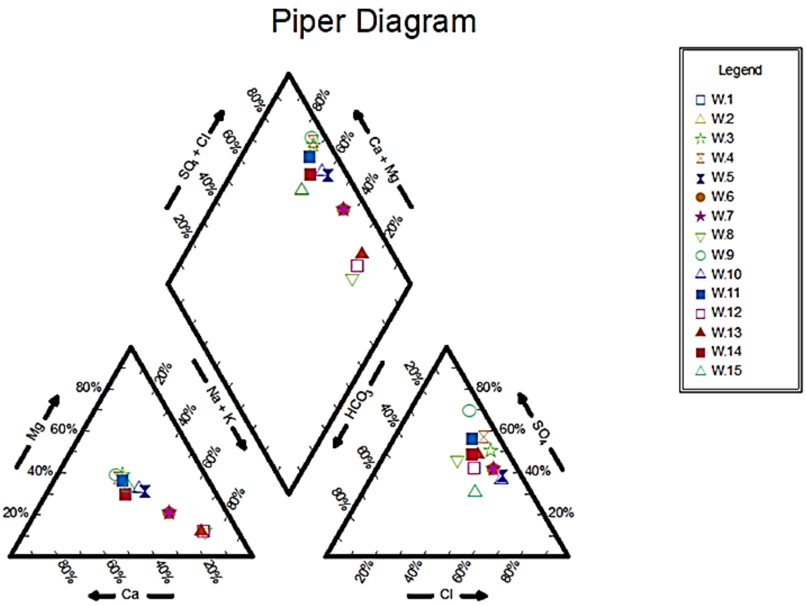


Figure 9: Piper diagram of the water tests in the study area

3.3 Groundwater Suitability for Different Purposes

The suitability of water for any use is related to its physical, chemical, and biological properties, and the motion of groundwater also enhances the concentration of the chemical species with a flow direction. Therefore, the suitability of water for any use is determined by the quality of chemical and biological elements, which are used for drinking, agricultural, and industrial purposes, as opposed to allowable limits [10].

3.4 Groundwater Suitability For Human Drinking

Groundwater suitability depends on various considerations, including chemical forms, chemical quantities, and biological influences. To determine the suitability of water for human use, the hydrochemical variations of groundwater samples are compared against the World Health Organization Standard and the Iraqi Standard (WHO, 2017) (IQS,2009). The results suggest that the groundwater in the research region is ideal for drinking water with some variations, including the concentrations of HCO_3 in certain wells (3,16). It shows that the water in the study area is unsuitable for drinking, and therefore its use should be avoided because it exceeds the permissible limit in Table7 (TDS, Ec, Cl, So_4, Hco_3).[11]

4. Groundwater Suitability for Irrigation Purposes

One of the most important factors that affect the physical properties of the soil and the crop yield is the sum of TDS and the sodium concentration in the irrigation water if used for long periods. Therefore, to find the suitability of well water for irrigation, the salt absorption ratio must be calculated by calculating the risk of sodium for crops.

SAR can be measured by the following formula [2]

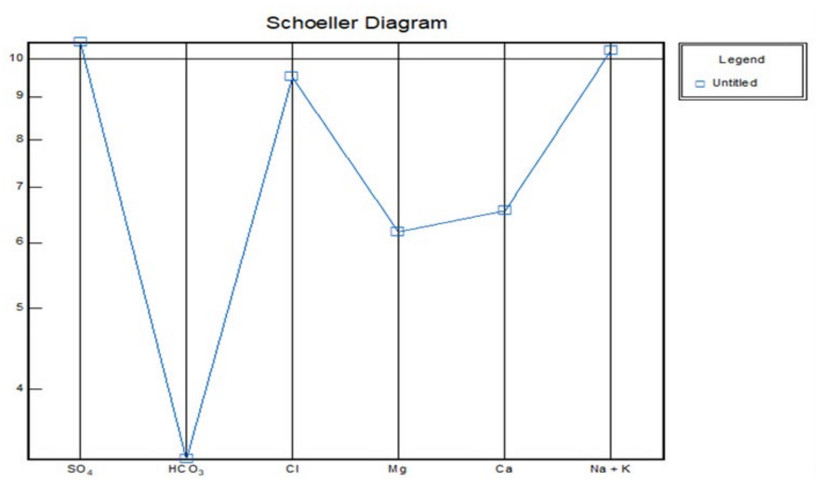


Figure 10: Schoeller's classification (1972) of the water in the study area

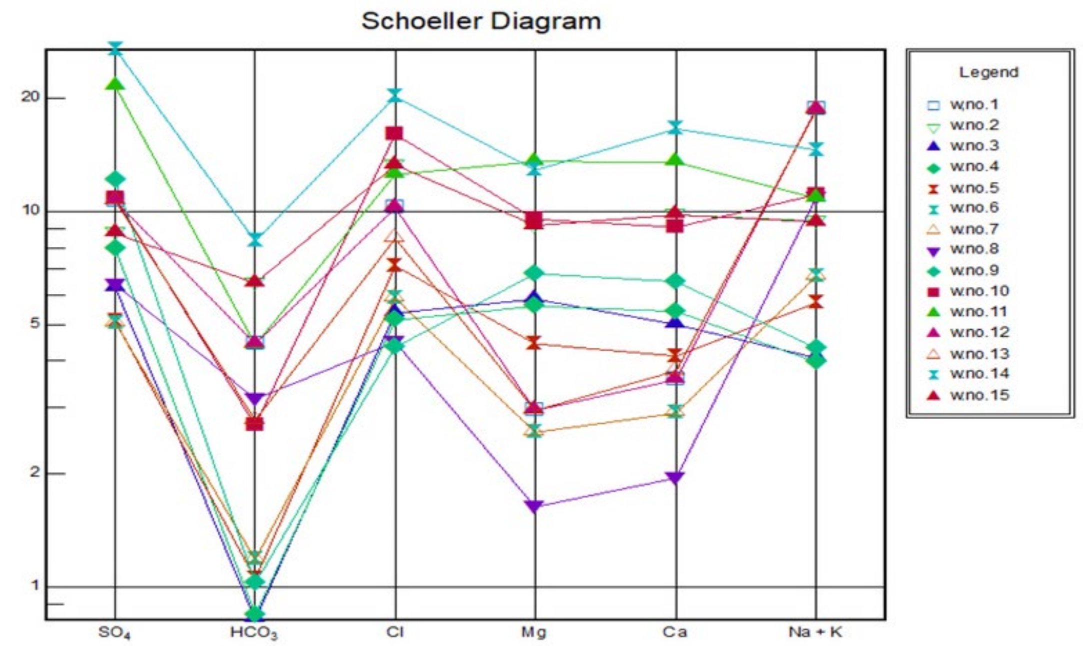


Figure 11: Schoeller's classification (1972) of the water in the study area

Table 5: Water Types according Schoeller classification (1972)

A	r (Na+K)>r Mg>rCa	1	r CL>r SO_4>r HCO_3
B	r (Na+K) >rCa>rMg	2	r CL>r HCO_3>rSO_4
C	r Mg>r (Na+K)>rCa	3	r SO_4>r CL>r HCO_3
D	r Mg>r Ca>r(Na+K)	4	r SO_4.r HCO_3>r CL
E	r Ca>r Mg>r(Na+K)	5	r HCO_3>r CL>r SO_4
F	r Ca>r(Na+K)>rMg	6	r HCO_3>r SO_4>r CL

Table 6: Hydrochemical indicators of groundwater samples for Study area

Well no	rNa/rCl	Water Origin
1	1.81	Meteoric
2	0.69	Marine
3	0.6	Marine
4	0.7	Marine
5	0.74	Marine
6	1.13	Meteoric
7	2.32	Meteoric
8	2.32	Meteoric
9	0.88	Marine
10	0.67	Marine
11	0.86	Marine
12	1.67	Meteoric
13	1.9	Meteoric
14	0.87	Marine
15	0.7	Marine

Table 7: A comparison of groundwater samples with WHO (2017) and IQS (2009) showed that standards of drinking water

Parameter	WHO,2017	IQS,2009	Range	Ave.	Exceeding Limits
PH	8.8 - 8.8	6.5 - 8.5	7.09-7.62	7.35	Not exceed
TDS	1000	1000	950-3800	2375	Exceed
EC	2500	2000	1268-4530	2899	Exceed
Ca^{+2}	200	150	58-270	146	Not exceed
Mg^{+2}	150	100	31-166	98.5	Not exceed
Na^{+}	-	200	88-354	171	Not exceed
K	-	-	5-5.36	5.18	Not exceed
Cl	250	350	154-716	435	Exceed
SO_4	250	400	242-1296	769	Exceed
HCO_3	-	200	51-509	280	Exceed
NO_3	50	50	1-28.8	14.9	Not exceed

Table 8: SAR and Na% of groundwater samples

Well No	Na%	SAR
1	74.25%	10.26
2	33.17%	3
3	27.32%	1.64
4	26.47%	2.3
5	40.13%	2.71
6	54.95%	4.0
7	54.95%	4.0
8	75.22%	8.00
9	24.52%	2.57
10	37.39%	3.04
11	28.58%	2.73
12	74.22%	10.33
13	73.38%	10.1
14	33.04%	3.75
15	33.07%	3.076

Table 9: Classification of Don (1995) for irrigation water

EC	TDS	SAR	Na	PH	Water quality
µs/cm	Ppm		%		
250	175		20	6.5	Excellent
250-750	175-525		20-40	6.5-6.8	Good
750-2000	525-1400		40-60	6.8-7.0	Permissible
2000-3000	1400-2100		60-80	7-8	Doubtful

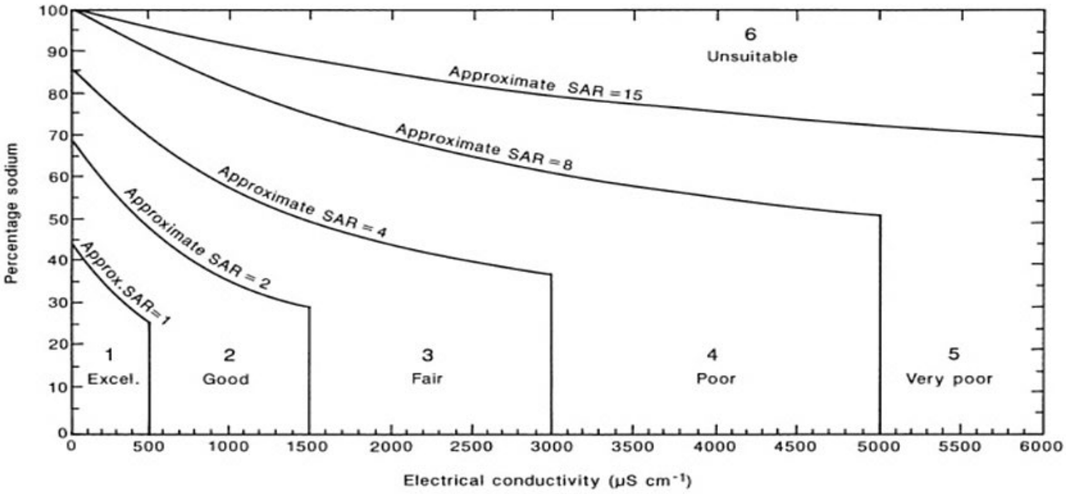


Figure 12: USDA classification [13]

$$SAR = rNa / [(rCa + rMg)/2]½ \quad (2)$$

The most comprehensive use of groundwater in the world is crop irrigation, so it is important to understand plant requirements with regard to the importance of groundwater. The key issues associated with low-quality irrigation water are excess salt content and elevated sodium concentrations (the sodium hazard), which raises the degree of the soil's acidity, which contributes to soil deterioration. In addition, the salinity threat allows the soil water to have higher osmotic pressure, which decreases the amount of water that plants can draw out of the soil [12].

Repair of calcium and magnesium by sodium adsorbed on clay The dispersion of soil particles results. When dry and gradually impervious to water, the soil becomes hard and dense so that the plant roots don't get enough water, even if water may be on the surface. Sodium adsorption estimates the sodium hazard in irrigation water SAR, which corresponds to the percentage of (Na^+ to Ca^{+2} and Mg^{+2}) in the water Table 8 [13] (Na %) can be estimated by using the formula

$$Na\ \% = [rNa + rK] / [rCa + rMg + rNa + rK] \times 100 \quad (3)$$

Don (1995) classification is used to determine the water suitability for irrigation, which dependson EC, TDS, pH, SAR and Na % Table 9.

The diagram classifies the irrigation water according to the percentage of sodium concentration and electrical conductivity (EC). The sodium adsorption index (SAR) is also shown. The six classes are described as follows:

- Class 1 (Excellent), the water is suitable for all crop types
- Class 2 (Good), suitable for most crops under most conditions, but limiting conditions can develop on poorly draining clayey soils.
- Class 3 (Fair), suitable for most crops if care is taken to prevent accumulation of soluble salts.
- Class 4 (Poor), suitable only in situations having very well-drained soils.
- Class 5 (Very poor), restricted to irrigation of sandy, well-drained soils in areas receiving at least (750) mm of rainfall.
- Class 6 Unsuitable for all crops [13].

Figure 11 and Table 9 show that all groundwater samples are considered good and Permissible except the wells. No.1, 8, 12, and 13 are unsuitable for all crops.

5. Conclusion

1. According to the (Schoeller classification, 1972), most of the water type (B3), while according to piper classification, kind of geological details is earth alkaline water with a substantial elevation of alkaline water with superimposed density of sulphate and chloride respectively.
2. The results of the hydrochemical formula show that most wells in the study area have water types of NaCl and $MgSO_4$ and the other wells $CaCl_2$, Na_2SO_4.
3. This research showed that groundwater in Al-Yusuifyia district is not suitable for drinking due to the high concentration of CL, SO4, HCO_3, and TDS, EC..because they exceed the standard limit of WHO.
4. For irrigation purposes, the well water is considered good and permissible except the wells no.1,8,12, and 13, according to table 8 and Table 9.

Author contribution

All authors contributed equally to this work.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

Conflicts of interest

The authors declare that there is no conflict of interest.

References

[1] B. K.. Deoli, S. K . Bartarya, N.A. Siddiqui, Assessment of surface and groundwater Quality of Haridwar district of Uttarakhand, Int. J. Chemtech Res., 10 (2017) 95-118.

[2] G. Matta, A. Kumar, Monitoring and Evaluation of River Ganga System in Himalayan Region with Reference to Limnological Aspects, World Appl. Sci. J. 33 (2015) 203-212. https://doi.org/10.5829/idosi.wasj.2015.33.02.72

[3] M. A. AL-Janabi, Hydrochemistry of the unconfined aquifer and the relationship of unsaturated zone sediments on the groundwaterButter Worth's, London2. K. R. Karanth, 2008.

[4] World Health Organization (WHO), 2007. Guidelines for drinking water quality. 3th ed., 1 (2017) 595, Recommendation, Geneva.

[5] M. Detay, Water wells implementation, maintenance and Restoration, John Wiley & Sons, London, 1997.

[6] N. M. Al Maimuri, A. R. Ali, A. M. Al-Sa'adi, Hydrogeologic sustainability and mitigation of Shallow Groundwater against High Saline and Chemical Pollutants, Eng. Technol. J., 37 (2019) 303-310. https://doi.org/10.30684/etj.37.3C.1

[7] IQS, Iraqi Standard, Iraqi Standard of Drinking Water 417 (2009), Second modification.

[8] A. H. AL-Fattlawi, G.Abukhanafer; A. AL- Salman; Removal of nitrate from contaminated groundwater using solar membrane distillation, Eng. Technol. J., 37 (2019) 327. https://doi.org/10.30684/etj.37.3C.4

[9] P. Land schoot; Irrigation water quality, Guidelines for Turfgrass sites,College ofagricultural sciences ,the Pennsylvania state university ,USA, CFM. 2007.

[10] C. M. Don, A grows guide to water quality, University College Station, Texas. 1995.

[11] C. W. Fetter. Applied hydrogeology, Charles Merrill publishing, Co. A. Bell and Howell Company, Columbus, Ohio, 1980.

[12] Hamill, L. and Bill, F. G. Groundwater resource development, 2013.

[13] M. S. Hussein, I. A.Alwan, & T. A. Hussain, Hydrogeological and hydro chemical evaluation of groundwater in Karbala region using Geographic Information System (GIS), Eng. Technol. J., 38 (2020) 515-522. https://doi.org/10.30684/etj.v38i4A.492

[14] FAO, AQUASTAT – FAO's global information system on water and agriculture, FAO, Rome, Italy.

[15] K. M. Hiscock. Rivett, M. O. Davison R. M, Sustainable groundwater development, Geological Society,UK, 2002.