Hydrochemical Evaluation of ground water Resources in Debagh –Makhmuar Basin North East of Iraq

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Abstract:
The aim of this study is to identify the water bearing zones in Debagh– Makhmuar basin, through a group of shallow and deep wells which were drilled in summer 2004. Two water bearing zones were identified in the study area. The hydrogeological setting of the basin was evaluated to suggest the optimal management of ground water resources. The unplanned, randomly drilling and excessive pumping of ground water without any scientific hydrogelogical evaluation causes a sharp decrease in ground water storage and led to the deterioration of ground water quality. Hydrochemical evaluation were carried out on the samples from shallow and deep wells in the basin, to assess the water quality for drinking and irrigation. Chemical analysis of ground water shows four water types: $MgSO_4$, $CaSO_4$, $MgHCO_3$ and $NaSO_4$. Statistical analyses were applied to find the relationship between the ions in ground water.

Introduction:
The demand for water has increased tremendously in the last 20 years due to the increase in population and the expansion of agricultural and industrial activities, ground water is preferable due to its lower cost and high quality. Villages in Debagh - Makhmuar basin depend on ground water for drinking, irrigation, and other uses. To satisfy the increased need for water, new wells have been drilled at various locations in the Debagh - Makhmuar basin. This study aimed to identify the aquifers, suggest optimal management of ground water resources and to understand the geochemical processes of precipitation ,dissolution and cation exchange that took place during water rock interaction, in addition it will provide information about the rock type of the aquifer. The concentration of dissolved ions in ground water generally governed by lithology ,velocity of ground water flow , nature of geochemical reactions , solubility of salt and human activities (Bhatt & Saklani ,1996).

Description of the study area:
Debagh - Makhmuar basin is the main hydrogeological basin in North East Iraq , the study area is situated (70) km South East of Mosul city , Fig (1) , between longitude (43° 30' 00") and (43° 54' 00") East and latitude (36° 00' 00")and   (35° 42' 00") North. The main topographic feature is Qara Chung anticline which is considered as the catchments area of the two sub basins , the first is Debagh in East, and the second is Makhmuar in West, the crest of the anticline represent a water divide between them. The climate of the area is semi-arid, the wet seasons are from November to April and the dry seasons are from May to October, according to the meteorological data of the last 25 years, the mean annual precipitation and evaporation rates are (380) mm/yr and (196) mm/yr (class A pan), respectively (Meteorological station in Mosul).
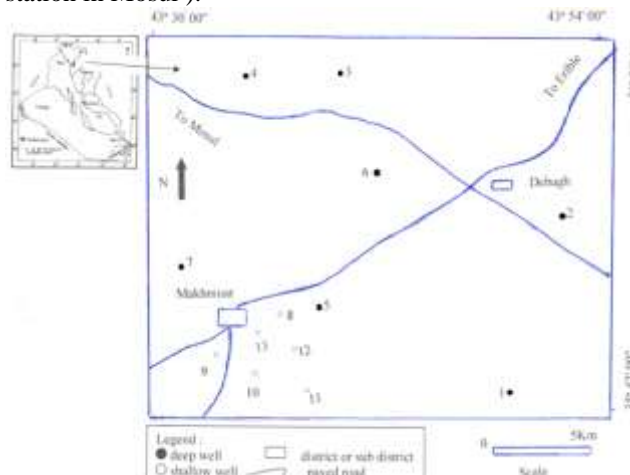

Fig (1) Location map of the study area (Parsons ,2003)

Geology and Hydrogeological setting:
The geological sequences in the study area extends from Avanah Formation (middle Eiocene) which is the older Formation outcrops in Qara Chunq anticline to the Quaternary deposits(Pleistocene)which are mostly covering the total area understudy (excluding) the upland area, Fig (2) .Quaternary deposits include flood plain deposits which consist of sand ,silt and clay and slope deposits which exposed as belt shape around the upland area which consist of rock fragment ,sand and silt, ploygentic deposits which cover approximately most of study area from quaternary deposits and consist of clay,sand and gypsum (Sisskian, 1992).
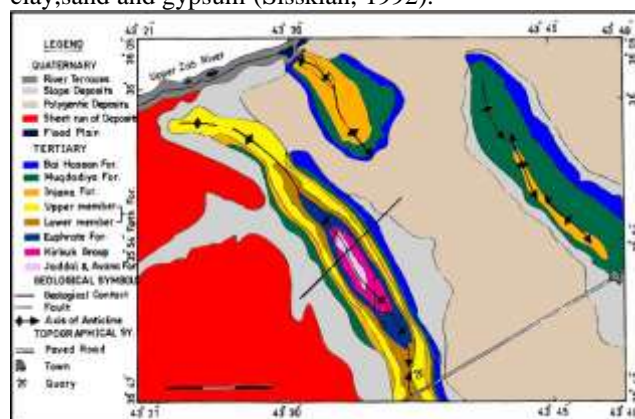
Fig (2)Geological map of the study area (O눈eure, 1996)

The other Formation is Bai Hasan which exposed mainly in Debagh basin and some vallies in Makhmuar basin, this Formation consists of sandstone, siltstone and claystone with fine gravel and conglomerate intercalation with clay and sand (Sisskian, 1992). The researchers chose the location of wells and supervise on the drilling ,collection of cutting samples and describe it to draw lithologic log for the wells , in addition to

measuring the yield of the wells Table (1). From the available lithologic logs, Fig (3) and measuring the static water level , two water –bearing zones were identified in the study area ,the upper aquifer is of quaternary deposits, the ground water in this aquifer is under unconfined condition in all localities, its thickness ranges from (5-30) m , static water level in this aquifer range from (9.5- 23) m below land surface . Recharging of this aquifer is direct from infiltration, the yield of this aquifer is low .

Fig (3) borehole lithology section of the deep wells in the study area

The second aquifer is Injana sandstone aquifer which considers as the main aquifer for supplying the water for drinking , irrigation and other purposes. The ground water in this aquifer occurred under semi-confined condition in most places to confined in others , water levels in this aquifer ranges from (21-46) m below land surface, there is hydraulic connection between Injana sandstone aquifer and Fatha aquifer which is directly below it and considered the third aquifer in region, (Al-ansari et.al ,1990).
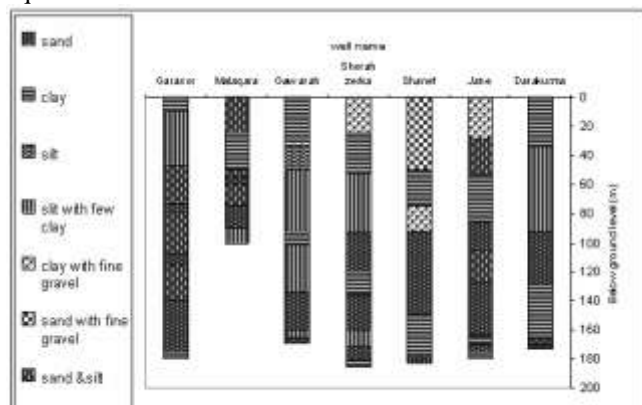
The general direction of ground water flow in Debagh basin from Qara Chunq mountain (recharge zone) toward the Upper Zab River ,while in Makhmuar basin ground water flow from Qara Chunq mountain toward Tigris River (Al-ansari et.al ,1990).

Sampling and analytical procedures:

Ground water samples were collected from seven deep wells, and six shallow wells after pumping for 10 min . pH, Electrical conductivity(EC) have been determined in situ, using the portable EC and pH meter.

All samples were collected in polyethylene bottles (1000 ml) and transported to the laboratory in cold storage. Each sample was analysed to determine the concentration (milligram/liter)of major ions (calcium, magnesium , sodium, potassium ,bicarbonate, sulphate , and chloride) in addition to total dissolved solids and total hardness .These water samples were analysed in the laboratory of Nineva Water Directorate using standard method (APHA,1975). The accuracy of the analyses was estimated from the ionic 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%, which ensured the realibility of the hydrochemical data.

Table (1) General Hydrogeological information about the wells in the study area

Location of well	Drilling date	Coordinates	Well Depth (m)	Well yield (L/Sec)	Static water level (m)	Dynamic water level (m)	Aquifer
1-Darakurma	July 2004	35 ° 44' 00.13" 43 ° 45' 01.35"	173	3.95	46	65	Injana Fm
2- Jane	July 2004	35 ° 51' 12.74" 43 ° 51' 04.86"	180	5.7	44	60	Injana Fm
3-Shanef	June 2004	36 ° 08' 50.77" 43 ° 30' 01.31"	182	6	21	37	Injana Fm
4- Shorah zerka	July 2004	35 °57' 51.81" 43 ° 36' 57.69"	185	5	25	55	Injana Fm
5- Gawarah	July 2004	35 ° 47' 27.37" 43 ° 38' 36.46"	170	6.15	45	55	Injana Fm
6- Malaqara	July 2004	35 ° 56' 44.45" 43 ° 38' 39.47"	100	4.75	25	50	Injana Fm
7- Garasor	June 2004	35 ° 49' 53.32" 43 ° 31' 08.56"	180	6.35	24	47	Injana Fm
8- Makhmuar(1)	April 2004	35 ° 46' 40.37" 43 ° 37' 30.16"	51	2.3	21	------	Quaternary
9- Makhmuar(2)	April 2004	35 °46 38.14" 43 ° 37 29.26"	39	2.5	23	-----	Quaternary
10- Kasran	April 2004	35 ° 46 34.18" 43 ° 37 35.28"	42	----	14.8	------	Quaternary
11- Makhmuar(3)	May 2004	35 °46' 36.04" 43 ° 37 ' 29.44"	21	-----	9.5	------	Quaternary
12- Makhmuar(4)	May 2004	35 °46' 37.58" 43 °37' 34.33"	27	------	18.3	------	Quaternary
13-Kansara Qal	August 2004	35 ° 45 ' 36.34" 43 ° 38' 44.18"	21	-------	11	-------	Quaternary

Table (2)chemical analysis of ground water samples showing major ions content and other parameters

No.	Location of well	Date	Tur [*]	pH	EC [**]	TDS	TH	Ca	Mg	Na	K	HCO$_3$	SO$_4$	Cl	irrigation water class
						mg / L									
1-	Darakurma	23/8/2004	0.8	7.6	1723	1257	660	96	102	97	15	156	691	78	C$_3$s$_1$
2-	Jane	3/8/2004	7.5	7.7	792	578	260	32	43	40	8	160	134	43	C$_3$s$_1$
3-	Shanef	3/8/2004	19	7.2	1906	1391	750	120	109	95	19	200	690	140	C$_3$s$_1$
4-	Shorah zerka	3/8/2004	1.4	7.6	1366	997	400	40	73	118	4	172	422	50	C$_3$s$_1$
5-	Gawarah	23/8/2004	0.6	7.4	1670	1219	820	160	79	25	3	234	397	86	C$_3$s$_1$
6-	Malaqara	23/8/2004	1	7.7	3750	2737	1680	240	164	51	16	296	513	360	C$_4$s$_1$
7-	Garasor	3/8/2004	34	7.2	2750	2007	972	209	87	61	7	188	531	167	C$_4$s$_1$
8-	Makhmuar(1)	22/5/2004	5.1	8	1209	774	340	28	73	8	1.8	180	224	25	C$_3$s$_1$
9-	Makhmuar(2)	22/5/2004	7.3	7.7	1225	784	360	42	71	7.5	1.9	200	226	30	C$_3$s$_1$
10-	Kasran	22/5/2004	0.7	8	586	375	230	32	44	15	1	203	95	22	C$_2$s$_1$
11-	Makhmuar(3)	1/6/2004	8	7.3	1462	935	380	45	74	6.5	1.8	200	250	25	C$_3$s$_1$
12-	Makhmuar(4)	1/6/2004	19	7.4	1459	933	370	29	71	19	3	195	223	20	C$_3$s$_1$
13-	Kansara Qal	15/9/2004	25	7.6	1674	1071	420	39	77	210	1	280	576	50	C$_3$s$_1$

* NTU   ** umohs/cm

Hydrogeochemical characteristics:

Chemical composition of all samples are shown in Table (2) and their locations are shows in Fig (1). Ground water shows high to moderate concentrations of calcium, magnesium, sodium, bicarbonate, chloride and sulphate according to (WHO, 1996), with ranges of 28-240 mg/L, 43-164 mg/L, 7.5-210 mg/L, 156-280 mg/L, 20-360 mg/L and 95-691 mg/L, respectively, the pH values are from(7.2 − 8), this values indicate that the water is alkaline (pH >7) . The concentration of total dissolved solid, ranged from (375 – 2737) mg/L . According to TDS classification (Davis & Dewiest, 1966), 53.8% of the ground water samples belongs to the fresh water (TDS < 1000 mg/L) and the rest are brackish water .All samples fall under hard class according to (Sawyer & McCarty, 1967) .

The major cations and anions for the analized water were plotted on a Piper diagram (Piper, 1944) after converting the concentration from mg/L to meq% to determine the water type Fig (4). According to this diagram four water types were found in this area, these are MgSO$_4$, CaSO$_4$, MgHCO$_3$, and NaSO$_4$. The first facies belongs to the wells No. (w$_1$,w$_2$,w$_3$,w$_4$,w$_6$,w$_8$,w$_9$,w$_{11}$,w$_{12}$) this facies is divided into two subgroups . The first subgroup, the cations are Mg^{+2} >Ca^{+2} >Na$^+$ and the anions are SO$_4^{-2}$ >HCO$_3^-$ > Cl$^-$, whereas the second sub group, the cations are Mg^{+2}> Na$^+$> Ca^{+2} and the anions are SO$_4^{-2}$ > Cl$^-$ > HCO$_3^-$, this facies is a domain facies and covers most of the area in deep and shallow wells . The source

of magnesium may be comes from clay minerals (illite and mg –chlorite). Illite and Mg –chlorite is derived from the weathering of rock of high content of Mg^{+2} (Sisskian, 1992) .The second facies CaSO$_4$ is found in the well (w$_5$,w$_7$), the sources of calcium and sulphate in the water comes from calcite and gypsum which is found as a secondary gypsum in Qaternary deposits as well as a wash of the outcrope of Fatha Formation during the rainfall . The third facies is unique facies which is found in (w$_{10}$) , and the last facies is also unique facies which is found in (w$_{13}$). Pearsons correlation matrices were used to find relationship between two or more variables was carried out using the statistical software (Swan & Sandiland, 1995) ,only correlations with (r > 0.4) are shown in Table (3).Samples showing(r > 0.7)are considered to be strongly correlated whereas(r > 0.5-0.7) show moderate correlation at a significant level (p)of < 0.05 (Adamis et.al., 2001) . strong correlations exist among TH,Ca^{+2},Mg^{+2},Cl$^-$,and EC (r > 0.7) Table (3). These relationships clearly identify the main element contributing the increase of salinity of ground water, due to the concentration by water–rock interaction and ion exchange. Ca^{+2}, Mg^{+2} and Cl$^-$ correlation with total hardness in strong correlation(r > 0.9) which is responsible for high value of hardness of permanent type, also strong correlation exist between total dissolved solid TDS and electrical conductivity EC (r = 0.995). Moderate correlation exist among EC, Ca^{+2}, Mg^{+2}, Na$^+$, K$^+$ and SO$_4^{-2}$ (r > 0.5-0.7).

Table (3) Pearson's correlation matrix of the hydrochemical data

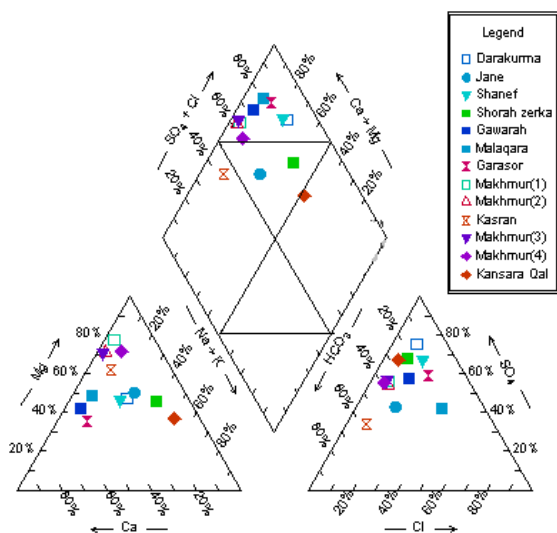|	pH	TDS	EC	TH	Ca	Mg	Na	K	HCO$_3$	SO$_4$	Cl
pH	1										
TDS		1	0.995	0.968	0.915	0.905		0.608	0.508	0.631	0.945
EC			1	0.954	0.889	0.907		0.563	0.545	0.615	0.928
TH				1	0.948	0.908		0.633	0.553	0.565	0.971
Ca					1	0.767		0.572	0.418	0.554	0.892
Mg						1		0.717	0.504	0.674	0.890
Na							1			0.687	
K								1		0.672	0.680
HCO$_3$									1		0.564
SO$_4$										1	0.513
Cl											1

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Fig (4) Piper diagram of water wells analyses illustrating the water types in the study area .

Evaluation of ground water for drinking and irrigation:
After reconnaissance on laboratory analysis of ground water samples in Debagh - Makhmuar basin, all water in deep wells are unsuitable for drinking except (w_5) in Jana village which is of excellent quality for drinking, while all shallow water wells are suitable for drinking except (w_{13}) in Kansara qal village which is unsuitable for drinking according (WHO,1996).Despite of some water wells are unsuitable for drinking due to slightly exceeding the permissible level, others still wells drinkable for the villages accustomed to this type of water (personal community) . Classification of water samples for irrigation (US salinity laboratory staff,1954) is given in Fig (5) and Table (2). Only one sample (w_{10}) is fresh water in the class C_2S_1,which has a medium salinity and low sodium hazard and which is suitable for irrigation, two samples are in the C_4S_1 and the rest in C_3S_1 class, which have low sodium hazard and high salinity hazard ,but they are suitable for irrigation.
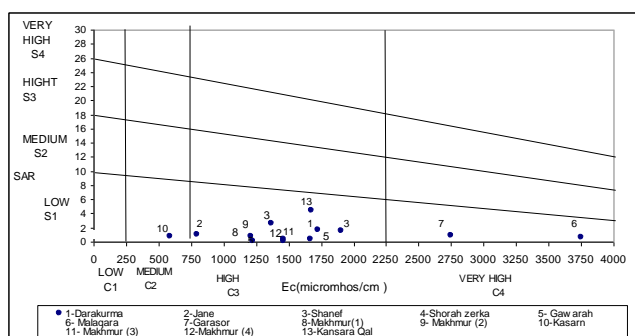
Fig (5) classification of water wells showing suitability for irrigation used on salinity hazard (US salinity laboratory staff 1954).

Conclusions and recommendations:
Ground water in Debagh -Makhmuar basin is from two water –bearing zones:
1- Quaternary aquifer that considers as a secondary aquifer and Injana aquifer that considered as the main aquifer for water supply.

2- These zones are usually separated by a thick layer of clay and /or silty clay,the upper zone is of unconfined condition and ranges in thickness between(5-25)m,the lower one is of semi-confined to confined condition.

3- water levels in the aquifers range from about (9.5-46)m below land surface, and ground water flows in Debagh basin toward Upper Zab River, while moves toward Tigris River in Makhmuar basin .

4- Chemical analysis of all water samples are showing slightly high concentrations for calcium, magnesium, sodium, bicarbonate, chloride and sulphate, and 53% of ground water samples are fresh water and the rest are brackish water.

5- A statistical analysis (Pearson correlation matrices) was applied to the hydrochemical data to find the relationship between two or more variables.

6- A according to Piper diagram Fig (4), four water types are recognized in the study area, these are $MgSO_4$, $CaSO_4$, $MgHCO_3$ and $NaSO_4$.

7- All shallow water wells are potable except the (w_{13}) which is unsuitable for drinking, while all the deep water wells is unsuitable for drinking except the (w_5) in Jana village which is excellent quality for drinking, all shallow and deep water wells are suitable for irrigation .

It was recommended that no need to drill water wells more than 200 m in depth, which is the maximum depth to Injana Formation, and to prevent reaching Fatha Formation, which has ground water of very high concentration of ions and causes deterioration of ground water quality. It was found that some wells penetrate this aquifer and causes mixing of water between the two aquifers, which lead to the deterioration of ground water in this basin.

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التقييم الهيدروكيميائي للمياه الجوفية في حوض ديبكة-مخمور، شمل شرق العراق

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الملخص:

تضمنت الدراسة التعرف على التكوينات الحاملة للمياه في منطقة حوض ديبكة – مخمور من خلال مجموعة من الابار الضحلة والعميقة التي حفرت حديثا ،حيث تم تميز خزانين حاملين للمياه في المنطقة وتضمنت الدراسة تقيم الوضع الهيدروجيولوجي للحوض ،من اجل الاستخدام الامثل لموارد المياه الجوفية ،أن عدم التخطيط والحفر العشوائي والضخ المتجاوز بدون أي تقيم هيدروجيولوجيي علمي أدى الى نقصان كبير في الخزين الجوفي بالإضافة الى تدهور نوعية تلك المياه .تضمنت الدراسة تقيم هيدروكيميائي لمياه الابار وتحديد صلاحيتها للشرب والاستخدامات الزراعية . تميزت المنطقة بوجود أربعة أنواع من المياه : هي كبريتات المغنسيوم ، كبريتات الكالسيوم ، بيكاربونات المغنسيوم وكبريتات الصوديوم ،وكذلك تضمنت الدراسة استخدام التحليل الإحصائي لإيجاد العلاقة بين الايونات الموجودة في المياه .