Evaluation of Groundwater Quality of Ainsifni Pila Spi Aquifer North-East of Mosul City/ North of Iraq

Taha Hussein Al-Salim **Ali Zain Al-Abdeen Al-Ozeer**

College of Environment, Univ. of Mosul

aalozeer@uomosul.edu.iq

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Abstract

Water quality is an important issue in ground water studies and is just as important as its quantity owing to the fitting of water for various purposes.

The main objectives of this study are to determine the chemical and physical characteristics of ground water of Ainsifni Pila Spi aquifer and to asses its quality for determining its suitability for domestics and irrigation purpose and to compare the concentration of both cations and anions with that of WHO. Ground water samples were collected from 8 drilling wells, during field work in Sept. 2014, for the analysis of their chemical composition of major cations and anions. The analysis comprises physical and chemical parameters of ground water such as; EC, pH, TDS, Na, K, Ca, Mg. HCO_3, CO_3, SO_4, CL and NO_3.

Chemical parameters such as, total hardness (TH), sodium percent (Na%) and sodium adsorption ratio (SAR), were calculated, based on the analytical results of ground water samples.

Basement rocks of the studied area which is crop out at the surface of ainsifni anticline, are represented by Pila Spi Formation of Middle Miocene age which consist of limestone. It is overlain by Quaternary sediments which are highly permeable beds.

Hydrochemical analysis are analyzed graphically using Piper diagram to determine the suitability and type of the groundwater. Sodium adsorption ratio (SAR) and sodium percentage (Na%) are also calculated to show the suitability of ground water for agricultural irrigation.

According to the results of chemical analysis of ground water samples, types of water are of $CaHCO_3$ and mix Ca-Mg-HCO_3. More over ground water samples are of moderate TDS which is within the specification of (TDS) values set up by the WHO, medium TH and generally groundwater of the studied are is of alkalinity in nature.

The over all quality of ground water samples of the studied area in most chemical constituents is on the moderate side in comparing with that of WHO due to its unique location away from any behavior of environmental pollutants. Rainfall water is the only source of replenishment to the groundwater aquifer.

Keywords: Groundwater quality, Aquifer, Cations and Anions, Piper Diagram

Introduction

In recent time, there has been a tremendous increase in demand for groundwater in the studied area due to the population grow and intense agricultural activities.

The irrigation-water supply in the study area is almost entirely based on ground water. Many deep wells have been constructed for the supply of irrigation water.

Very useful hydrogeological data, such as lithological units of deep well, water level depth and geological prospecting, were obtained.

The aquifer in the studied area consist mainly of the Pila spi limestone which crop out at the surface of the ground of Ainsifni anticline. Pila spi formation of more than 150 meters in thickness forms the only sources of groundwater in the area.

The quality of ground water is showed little variation and differs slightly from season to another due to the homogeneity of the aquifer rocks and the difference in rainfall quantity, recharge, fluctuation change of water level and dissolution between water and host rocks.

Rainfall is the main sources of recharging the ground water of the studied area. Short and heavy rainfalls are directly affect the recharge in the area due to the presence of structural features such as joints, fractures and cracks.

The depth to the ground water level of deep wells in the studied area range between 10-22 meter during rainy season, while in dry season range between 18-41 meter.

Ground water quality assessment for drinking and irrigation has become a necessary and important task for present and future groundwater quality management and sustainability of groundwater.

People in the studied area abstracted water from deep wells to meet their agriculture irrigation needs and domestic purposes. Such water type needs to be of appropriate quality.

The authors have referred several aspects of chemical data and discussed the principle characteristics of ground water quality classifications for domestics and irrigation purposes. In view of this, an attempt has been made to analyze the groundwater quality of the studied area to determine the exact level of physico-chemical parameters and find out best water type to be used in different purposes by people in the study area.

Material and Methods

Location and description of study area

The study area is situated in the north estern part of Mosul city and located approximately between latitude 36 6905 – 36 71 00 and longitude 43 26 15 – 43 35 00 . It covers an area of about 60 $km^2$with its elevation varying from 550 - 700 m above sea level Fig. (1). The climate is considered to be semi-arid and the annual precipitation being approximately between (320-400) mm. 90% of the total rainfall occurs from Oct.- April. Coarse textured patterns noticed in the plains indicating high rainfall infiltration. The most important activity of the area is agriculture, and the chief crops are wheat, barley and vegetable.

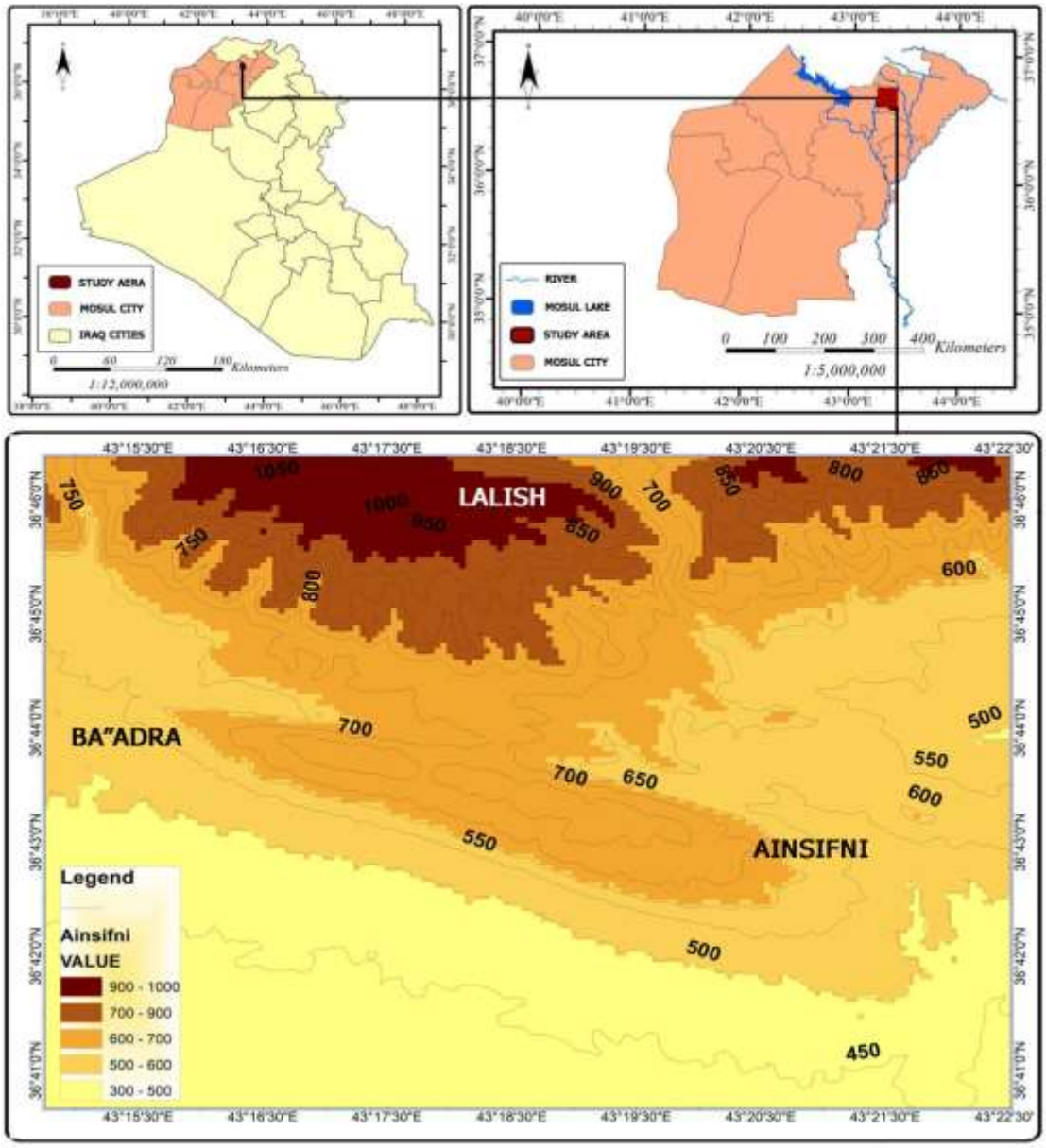

Fig. (1) Location of the study area.

Sample collection and analysis:

Ground water samples were collected from (8) deep wells shown in Fig. (2) of the studied area during Oct.. 2013. The chemical analysis were carried out in the laboratories of the Department of soil and water /college of agriculture, Mosul University according to the methods adopted by the U. S. Geol. Survey, [1]. Electrical conductivity (Ec), (pH), (TH) and (TDS)were measured in the field immediately after sampling. Water samples collected were analyzed for major cations (Ca, Mg,Na, and K) and major anions (HCO_3, CO_3, SO_4,Cl, and NO_3). All measurements and major ion analysis are presented in table (1).

Fig. (2) Well location of the study area.

Table (1) Chemical constituents in (ppm) of groundwater wells of the study area.

Well No.	Ca	Mg	Na	K	Cl	NO_3	SO_4	HCO_3	TDS	EC	pH
1	39.2	33.8	2.9	0.9	3.0	2.6	15.9	251	379	472	6.9
2	53.4	20.1	3.2	1.3	3.8	2.4	17.1	234	369	466	7.1
3	29.1	36.7	18	1.1	3.0	2.19	11.8	258	368	393	7.1
4	60.7	13.3	11	0.6	3.2	2.78	12.4	222	333	342	7.0
5	48.3	12.6	13	0.7	2.0	3.5	6.3	217	344	351	6.9
6	46.9	14.8	15.8	0.8	2.4	4.11	5.7	227	352	364	7.2
7	57.2	23.9	6.7	0.4	5.9	3.8	36.2	231	277	339	7.4
8	47.6	26.4	8.1	1.2	4.8	4.6	33.4	246	315	327	7.2
Max.	60.7	36.7	18	1.3	5.9	4.6	36.2	258	379	472	7.4
Min.	29.1	12.6	2.9	0.4	2.0	2.19	5.7	217	277	327	6.9

Geology setting:

The study area is represented as a part of ainsifni anticline and stratigraphically, is dominated by Pila Spi geological formation of Upper Eocene cropped out at the surface of earth at the top of Ainsifni anticline as shown in fig. (3) and extended downward with laterally inclined to become the bottom bed of the syncline as shown in fig. (4) . This formation consist of two members [2], the upper member of thickness about 60 meters, consist of well bedded bituminous limestone and chalky limestone recrystallized with a belt of white chalky marls with chert nodules. The upper member characterized by the presence of structural features such as fractures, cracks and joints which help the infiltrated rainfall to recharge the groundwater aquifer. The lower member of Pila Spi formation consists of massive limestone of white color with the presence of dolomite due to dolomitization.

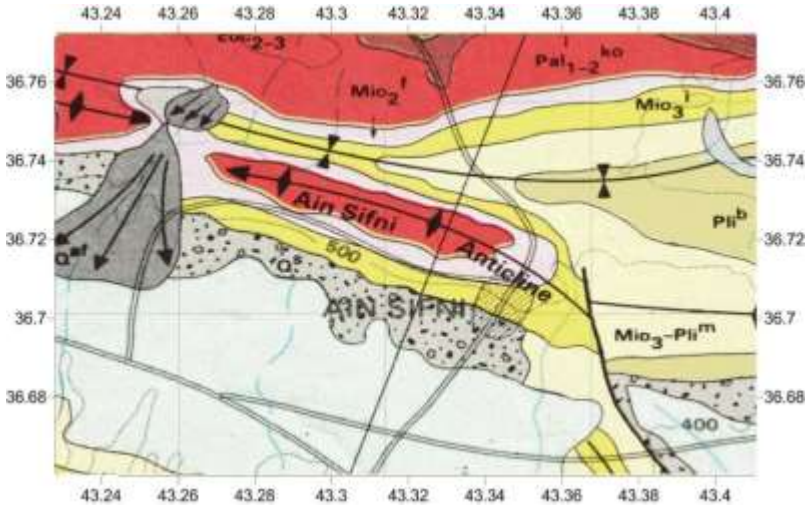

Fig. (3) Geology of the study area.

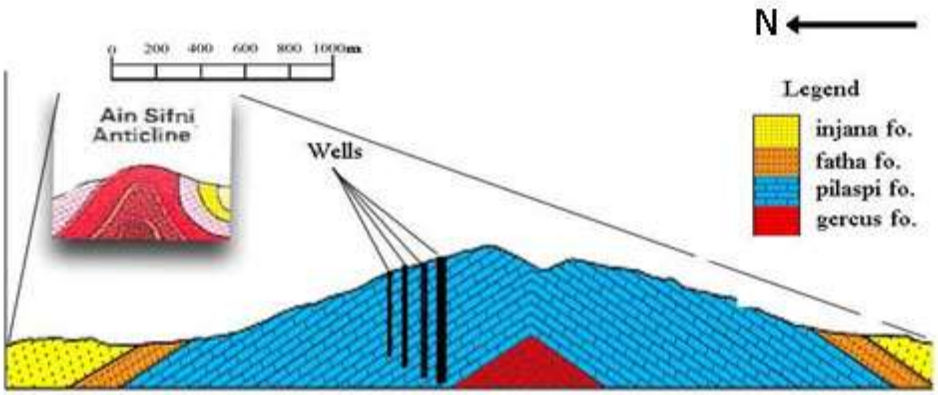

Fig. (4) Geological cross-section show cropped Pila Spi Formation and drilling well site.

Hydrogeology Setting:

The hydrogeology of the study area is interpreted on the basis of the available documentary evidence and records such as bore hole lithology fig. (5) and geology.

Pila spi formation is cropped out at the top of ainsifni anticline and formed unconfined aquifer. This formation is formed the upland recharge area to the aquifer which receive directly the rainfall during rainy season. Rainfall is the main source of aquifer recharge, that infiltrated downward through the structural features, such as fractures, joints and cracks of the pila spi formation to recharge the groundwater aquifer. Drilled wells (1 and 5) shown in fig. (5) penetrating pila spi aquifer diagonally to the depth of 150 m. and 160 m. respectively.

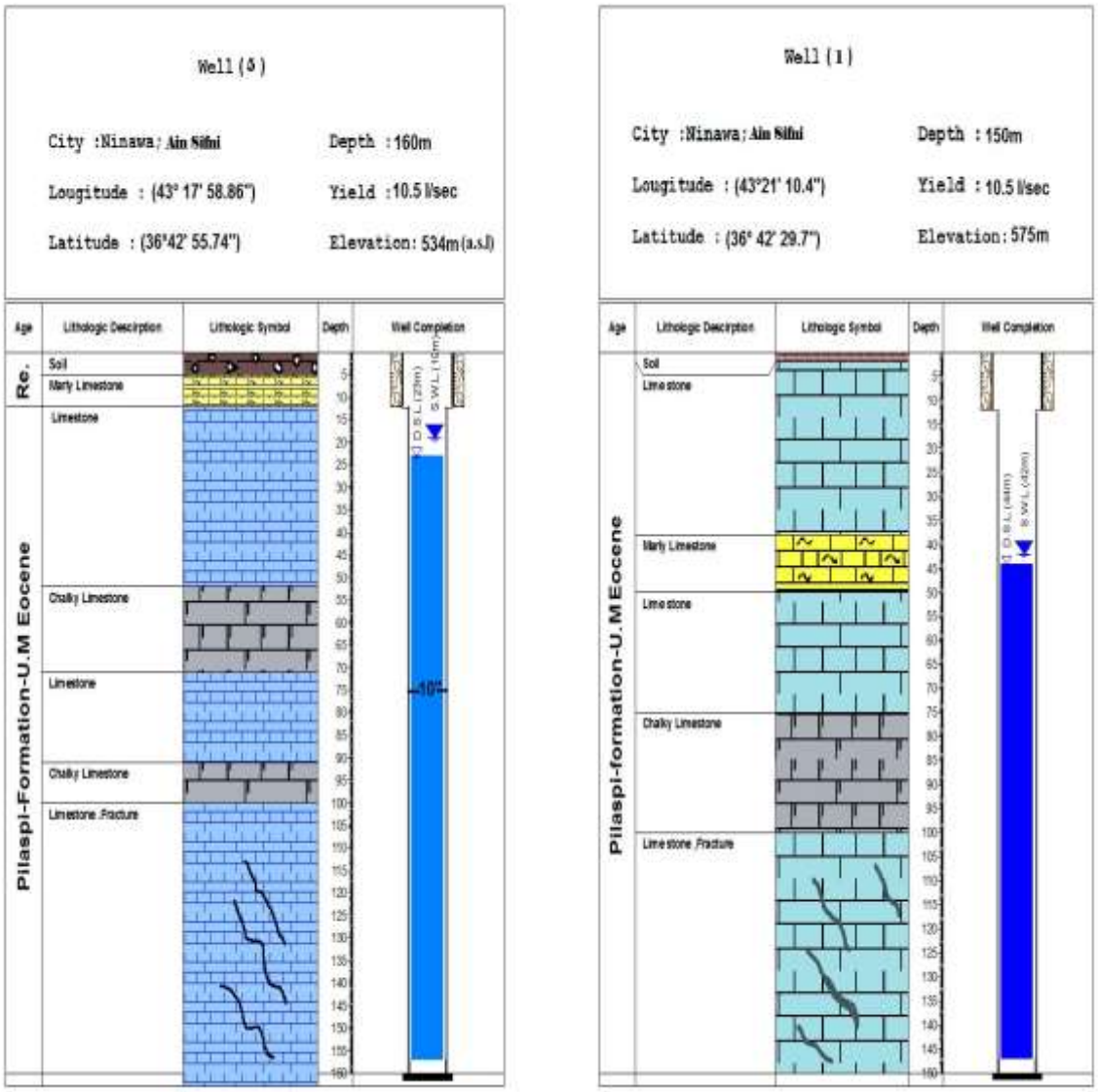

Fig.(5) Bore hole lithology

Results and Discussion:-

Hydrochemistry:-

The different composition of groundwater type of wells of the study area result from numerous hydro chemical processes, among of these processes is the interaction between ground water and host rocks. The concentration of dissolved ions in ground water samples are generally governed by lithology, velocity and quantity of ground water flow, nature of geochemical reactions, solubility of salts and human activities[3,4]. The variation on the concentration levels of the different hydrogeochemical constituents dissolved in water determines its usefulness for domestic, industrial and agricultural purposes [5]. Quality of groundwater is equally important to its quality owing to the suitability of water for various purposes [6].

TDS is an important parameter to be considered ingroundwater quality, because many of the toxic solid materials may be imbedded in the water, which may cause harm to the plants [7]. The total dissolved solids (TDS) of groundwater samples of the study area is ranged between (277-379) ppm and found within the specification of (TDS) values set up by the [8]. The excess of TDS in the analysis is caused by mixing of surface pollutants during the infiltration and percolation of rainwater downward and the interaction between the groundwater and host rocks.

Electrical Conductivity is(Ec) a sign of the amount of salts dissolved in water. It is useful as a general measure of groundwater quality. Conductivity is a measure of the ability of water to pass an electrical current. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). Conductivity is also affected by geology and temperature, the warmer the water the higher the conductivity.

The value of electrical conductivity of groundwater samples of the study area range from (327) mmhos to (472) mmohs which is indicated that all samples are in safe side for different purposes.

The pH value is a good indicator of whether water is hard or soft. The pH of pure water is 7. In general, water with a pH lower than 7 is considered acidic, and with a pH greater than 7 is considered basic. The normal range for pH in surface water systems is 6.5 to 8.5, and the pH range for groundwater systems is between 6 to 8.5. The pH value of ground water samples in the study area fluctuate within the narrow limits between (6.9) and (7.4).

Chemical parameters such as, total hardness (TH), sodium percent (Na%), sodium absorption ratio (SAR) were calculated, based on the analytical results of ground water samples as shown in table (2).

The total hardness TH is one of the factors that establishes the quality of a water supply. Originally, was understood to be a measure of the capacity of water to precipitate soap. Soap is precipitated chiefly by the calcium and magnesium ions present in water. Total hardness is defined as the sum of the calcium and magnesium concentrations, both expressed as calcium carbonate, in milligrams per liter and can be calculated by the following equation:

Total Hardness [TH] = 2.497 [Ca] + 4.118 [Mg]

The TH value of groundwater samples of the studied area is ranged between 172.49 – 237.07 mg/l which revealed that All groundwater samples are moderately hard.

Sodium percentage (Na%):

Sodium concentration is important in classifying irrigation water because sodium reacts with soil to reduce its permeability. Sodium content is usually expressed in terms of percent sodium (Na%). The Na% values of groundwater samples range from (0.68%) to (17.11%). The sodium percentage (Na%) is calculated using the following formula:

$$Na\% = \{ (Na + K) / (Ca+Mg+Na+K) \} * 100$$

Where all the concentration are expressed in meq/l.

The Na% ofall groundwater samples of the studied area indicates that the ground water is good for irrigation (Ragunath, 1987).

Sodium Adsorption Ratio (SAR):

The sodium adsorption ratio (SAR) is generally considered an effective evaluation index for most water used in irrigated agriculture [9].

It is also a standard diagnostic parameter for the sodicity hazard of a soil, as determined from analysis of pore water extracted from the soil [10].

The formula for calculating the sodium adsorption ratio (SAR) [11]is:

$$SAR = Na / sqrt [(Ca + Mg)/2]$$

Where all ionic concentration expressed in epm.

The SAR value of groundwater samples range from 0.07 to 0.62 which is fell in the low sodium class. This implies that no alkali hazard problem to the crops. When SAR is less than 3, there will not be a problem, [12].

Although SAR is only one factor in determining the suitability of water for irrigation, in general, the higher the sodium adsorption ratio, the less suitable the water is for irrigation. Irrigation using water with high sodium adsorption ratio may require soil amendments to prevent long-term damage to the soil [13].

Table (2) Chemical parameters of groundwater samples of the study area.

Well No.	TH	SAR	Na%
1	237.07	0.07	0.68
2	216.11	0.09	3.86
3	223.79	0.62	15.8
4	206.34	0.46	11.06
5	172.49	0.39	14.94
6	178.05	0.51	17.11
7	241.25	0.55	6.08
8	227.57	0.53	8.01

Hydrochemical Facies:

Groundwater quality is defined by the chemical constituents in the water and the chemical analysis data can be understood by using Piper diagram. [14].

Rock Work, 2006 Software has been employed to calculate and plot the concentration of chemical constituents of groundwater samples using Piper Diagrams which is used to illustrate the major ions composition of groundwater samples as shown in Fig. (6).

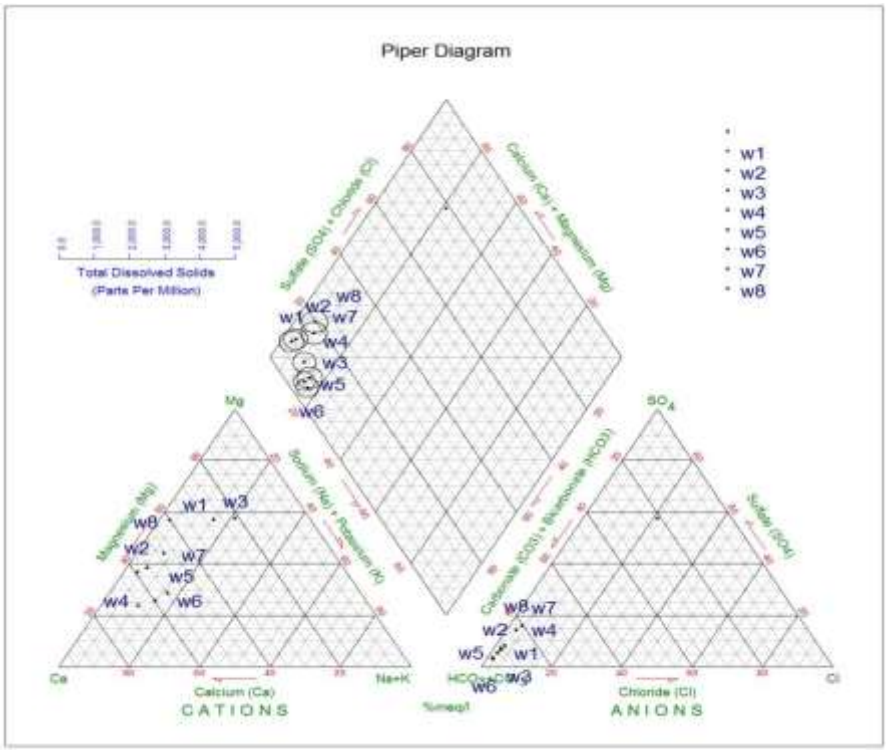

Fig. (6) Piper Diagram.

This diagram is particularly useful for detecting changes or trends in groundwater chemistry across an area or through time [15]. Piper diagram shows that most groundwater samples are normal earth alkaline water with prevailing bicarbonate of mixed of Ca- HCO_3 type.

Conclusion:

This paper presents general guide lines for the variations in the chemical composition of ground water of the of chemical analysis of groundwater samples and the suitability of groundwater for domestics and agricultural purposes. The chemical analysis of groundwater reveals that the ground water is moderately hard, fresh to saline and alkaline in nature.

The pH value of groundwater samples is range between (6.9-7.4). The EC value range from 327 μmohs to 472 μmohs.

Total hardness TH value range from 172.49 – 241.24 mg/l and shows that the majority of ground water samples fall in the moderately hard water. Groundwater in such condition and within the specification of WHO may not be hazardous to health of people and also may not be objectionable to a large number of people.

The SAR value of groundwater samples range from 0.07 to 0.62 which is fell in the low sodium class. The Na% values of groundwater samples range from (0.68%) to (17.11%) which indicates that all the groundwater samples are good for irrigation.

The results of the analysis of the groundwater samples of the studied area are of good quality. This needs current controls to preserve surrounding environments and keep it away from any environmental pollutants such as human activities, agriculture and fertilizers because of its negative impacts on the groundwater aquifer .

Conflict of Interests.

There are non-conflicts of interest .

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الخلاصة

تعتبر نوعيه المياه مسالة هامة في دراسات المياه الجوفية ، بالاضافة الى كميتها في استخدام المياه لأغراض مختلفة.

وتتمثل الأهداف الرئيسية لهذه الدراسة في تحديد الخصائص الكيميائية والفيزيائية للمياه الجوفية في الطبقة المائية المتمثلة في تكوين البلاسبي، وتقويم نوعيتها لتحديد مدى ملاءمتها واستخدامها لأغراض الشرب للانسان والري ومقارنه تركيزالأيونات الموجبة والسالبة الرئيسية فيها مع معاييرمنظمة الصحة العالمية (WHO). وتم جمع عينات من المياه الجوفية من 8 ابار واقعة ضمن تكوين البلاسبي في 2014 سبتمبر لتحليل تركيبها الكيميائي وتحديد تركيزالأنيونات والكتيونات الرئيسية. ويشمل التحليل البارامترات الفيزيائية والكيميائية للمياه الجوفية مثل:

(EC, pH, TDS, Na, K, Ca, Mg. HCO3, CO3, SO4, CL, NO3)

اما البارامترات الكيميائية مثل ، العسرة الكلية (TH) ، والنسبة المئوية للصوديوم (Na%) ونسبه امتزاز الصوديوم (SAR) ، تم حسابها بالأعتماد على النتائج التحليلية لعينات المياه الجوفية.

صخور الطبقة المائية في المنطقة المدروسة لتكوين البلاسبي منكشفة على جناحي طية عين سفني ، ويتمثل تكوين البلاسبي في عصر المايوسين الأوسط والذي يتكون من الحجرالجيري, والذي يكون مغطى بطبقة سميكة من رواسب العصر الرباعي التي تتميز بنفاذية عالية وتوزيع جغرافي واسع النطاق.

أُستخدمت في التحليلات الهيدروكيميائية والتمثيل البياني، الرسم التخطيطي لبايبر(Piper diagram) لتحديد مدى ملاءمة ونوعية المياه الجوفية. وكذلك تم حساب نسبة امتزاز الصوديوم (SAR) والنسبة المئوية للصوديوم (Na%) لإظهار مدى ملاءمة المياه الجوفية للري الزراعي.

ووفقاً لنتائج التحليل الكيميائي لعينات المياه الجوفية، فان أنواع المياه هي من نوع ($CaHCO_3$) مع ($Ca-Mg-HCO_3$). كما لوحظ على اكثر عينات المياه الجوفية معتدلة من حيث TDS والتي هي ضمن المواصفات القياسية للقيم التي وضعتها منظمة الصحة العامة، والمياه الجوفية عموماً في منطقة الدراسة هي مياه قلوية في الطبيعة.

جميع عينات المياه الجوفية ضمن المنطقة المدروسة في معظم المكونات الكيميائية تقع على الجانب المعتدل مقارنه مع محددات منظمه الصحة العامة وذلك لموقعها الفريدة من نوعها بعيدا عن اي سلوك من الملوثات البيئية. ماء الامطار هو المصدر الوحيد لتجديد مياه الجوفية

الكلمات الدالة: الايونات الرئيسية الموجبة والسالبة, الكتيونات، الايونات، البلاسبي، امتزاز الصوديوم، قلوية،البارامترات.