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Mitrid Groundwater Evaluation for Irrigation, Northern West Libya

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ABSTRACT

This study was carried out to analyse groundwater quality for irrigation purpose in Mitrid City. Fifteen samples from different sites of selected study area were collected and analysed for major anions and cations. The suitability of the groundwater for irrigation were evaluated based on the TDS, EC, Sodium Absorption Ratio (SAR), Kelly's Ratio (KI), Sodium Percentage (Na%), Soluble Sodium Percentage (SSP) and Permeability Index (PI). The calculated parameters show that the majority of the groundwater samples are suitable for irrigation uses. According to the Gibbs diagram, groundwater in the study area is dominated by evaporation followed by rock–water interaction process. Also the Wilcox diagram classify the groundwater as good to doubtful category. Generally, the groundwater in the study area is good for irrigation purposes.

تقييم المياه الجوفية للري في المطرد، شمال غرب ليبيا

وفاء الهادي الذيب[1] عمر احمد القايدي[2]

استهدفت هذه الدراسة تقييم المياه الجوفية بمنطقة المطرد لأغراض الري. تم جمع وتحليل خمسة عشر عينة من مواقع مختلفة من منطقة الدراسة المختارة للأيونات والكاتيونات الرئيسية. تم تقييم مدى ملاءمة المياه الجوفية للري بناءً على المواد الصلبة الذائبة الكلية، الموصلية، نسبة امتصاص الصوديوم، مؤشر كلي، نسبة الصوديوم، نسبة الصوديوم القابلة للذوبان ومؤشر النفاذية. توضح البارامترات المحسوبة أن غالبية عينات المياه الجوفية مناسبة لاستخدامات الري. وفقًا لمخطط جيبس(Gibbs)، فإن المياه الجوفية في منطقة الدراسة يغلب عليها عملية التبخر تليها عملية التفاعل بين الصخور والمياه. صنف مخطط ويلكوكس(Wilcox) نتائج المياه الجوفية أيضًا بانها جيدة الى مقبولة. بشكل عام، تعتبر المياه الجوفية في منطقة الدراسة جيدة لأغراض الري.

INTRODUCTION

Groundwater is the main source of water used for agricultural and industrial human activities in the countries where surface water is in short supply. Therefore, the assessment of groundwater quality and its sustainable use are of paramount importance in arid and semi-arid agricultural regions, where irrigation water is of critical social and economic importance, (Zuane, 1997; Kumar *et al*., 2006; Delgado *et al*., 2010).

Generally, the quality and quantity of groundwater mainly depends on the geochemistry of soils and rocks through which water flows before reaching the aquifers, on the balance of precipitation and evaporation, the quality of recharged water (Al-Shaibani, 2008; Chidambaram *et al*., 2011; Prasanna *et al*., 2011; Fipps, 2003; Asawa, 2014).

Many scientists have focused attention on the negative effects of irrigation water quality on soil properties and crop yields (Bezborodov *et al*., 2010; Pang *et al*., 2010;

Pedrero *et al*., 2010; Ghazaryan *et al*., 2016). The results of the various investigations have shown that the evaluation of groundwater quality is needful for the protection and proper management of agricultural land (Mitra *et al*., 2007; Zhang *et al*. 2011; Li *et al*, 2012; Nagaraju *et al*, 2017; Asante-Annor *et al*., 2018; M.K.N. Kumar *et al*. 2019).

The major water ions are used to classify groundwater based on the basic element compounds of cations and anions of dissolved salts in water. The aims of this study were to evaluate the groundwater quality status for irrigation purpose using water quality indices such as Salinity index; electrical conductivity (EC) and total dissolved solids (TDS), Sodium Absorption Ratio (SAR), Kelly's Ratio (KI), Sodium Percentage (Na%), Soluble Sodium Percentage (SSP) and Permeability Index (PI), and diagrams such as Wilcox and Gibbs.

MATERIALS AND METHODS

The study area is in the western side of Azawia in Mitrid city, and is located between latitudes 32°47'13.37"N to 32°41'34.52"North and Longitude 12°35'10.68" to 12°37'59.60"E, Figure (1).

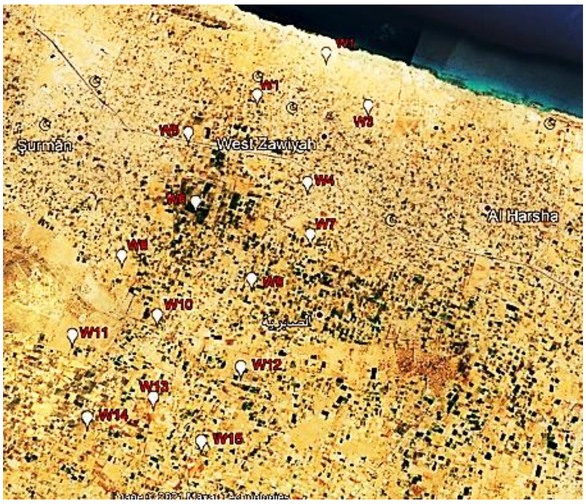

Figure (1): The location of the samples.

The present research work is based on 15 ground water samples collected from the study area in Mitrid Libya. The groundwater samples were collected in pre-cleaned polyethylene bottles from bore wells as per the standard procedures. The samples have collected, after 5 minutes of run-off water drawn from wells. The water samples were analyzed for various parameters which include electrical conductivity (EC), total dissolved solids (TDS), cations such as calcium (Ca^{++}), magnesium (Mg^{++}), sodium (Na^{+}) and potassium (K^{+}); and anions as Chloride (Cl^{-}), bicarbonate (HCO_3^{-}), Sulfate (SO_4^{--}) and nitrate (NO_3^{-}). The groundwater chemical composition were measured to determine the concentrations of sodium ions (Na^{+}), potassium ions (K^{+}), the water samples contents of these cations is measured using Flame photometer. The total HARDNESS calcium ions (Ca^{++}), magnesium ions (Mg^{++}) was determined by EDTA titrimetric method. Chloride ions (Cl^{-}) was determined by silver nitrate titration. Carbonate ions (CO_3^{--}) and bicarbonate ions (HCO_3^{-}) were determined by sulfuric acid. Sulfate ions (SO_4^{--}) and nitrate ions (NO_3^{-}) contents were determined using spectro-photometer. The Salinity refers to the amount of total dissolved solids (TDS) in the water and is frequently measured by electrical conductivity (EC). Waters with higher TDS concentrations will be relatively conductive. TDS is measured in parts per million or mg/L and EC is measured in micro-Siemens per centimeter (µS/cm). The general formula adopted to calculate the TDS (Kelly, 1946) is:

$$\textbf{TDS (mg/L)} = \mathbf{0.64 \cdot EC} \ldots\ldots\ldots\ldots..(\mathbf{1})$$

The statistical parameters and the major ion-concentrations are tabulated in Table (1).

Table (1): Groundwater chemical analyses (meq/L):

Well No.	EC µS/cm	TDS mg/L	Ca^{2+}	Na^{+}	Mg^{2+}	K^{+}	HCO_3^{-}	SO_4^{2-}	NO_3^{-}	Cl^{-}
1	6900	4416	380.1	470.1	134.2	13.5	410.8	345	44	950.5
2	7500	4800	450.5	552.5	465.5	25.5	341.19	550	48	865
3	5480	3507.2	358.4	556.9	265.5	27.8	264.5	450	35	830
4	4660	2982.4	420.5	420.5	105.5	11.5	142.42	495	48	750
5	1400	896	230.4	133	58.5	7.5	162.77	285	35.5	178.7
6	1150	736	178.5	163	23.81	7.5	152.59	245	33.5	275.5
7	1550	992	145.5	125.5	64.5	3.8	203.46	160	44.5	188.5
8	2460	1574.4	138.5	128.5	28.4	6.1	132.25	128	49.8	255.7
9	1310	838.4	145.2	110	20.5	6.4	152.59	115	34.5	223.6
10	2470	1580.8	177.4	108.2	37.5	6.2	142.42	195	33.5	296.59
11	4300	2752	265.5	193	81	7.8	203.46	450	31.5	278.4
12	2080	1331.2	275.5	188.5	28.5	5.6	193.28	465	41.5	375.5
13	2235	1430.4	335.5	165	157	10.7	193.28	550	23.5	560.1
14	1645	1052.8	188.5	146.5	40.5	9.8	122.08	380	35.5	358.4
15	1290	825.6	88.5	163.5	19.5	8.8	152.59	419	44.5	325.4

RESULTS AND DISCUSSION

Water quality parameters major cations as Na^{+}, Ca^{2+}, Mg^{2+}, K^{+} and anions Cl^{-}, SO4^{2-}, HCO_3^{-}, CO_3^{2-}, NO_3^{-} were used to determine SAR, KR, Na%, SSP, PI, R1, and R2 in Table (2).

1. Sodium Absorption Ratio (SAR)

The sodium adsorption ratio is an indicator of the relative proportion of sodium ions in a water sample to those of calcium and magnesium. SAR is used to predict the sodium hazard of water. It is formulated as Eq. (2):

$$\boldsymbol{SAR = \frac{Na}{\sqrt{\frac{Ca+Mg}{2}}}} \ldots\ldots\ldots\ldots(2)$$

Water having SAR values <10 is considered excellent, 10-18 is good, 18-26 is fair and above 26 is unsuitable for irrigation use (Kelly, 1946). The SAR values varied from 1.86 to 5.43 and have been classified as excellent and suitable for irrigation (Table 2).

Table (2): Groundwater quality indices for irrigation purpose.

Well No.	SAR	KI	Na%	SSP	PI	R1	R2
1	5.28	0.68	40.92	40.52	46.03	0.52	0.80
2	4.36	0.40	28.87	28.33	31.64	0.52	0.81
3	5.43	0.61	38.55	37.87	41.77	0.58	0.84
4	4.75	0.62	38.52	38.14	41.68	0.47	0.90
5	2.03	0.35	26.81	26.18	34.15	0.34	0.65
6	3.04	0.65	40.12	39.48	48.84	0.45	0.76
7	2.18	0.43	30.65	30.28	40.73	0.43	0.61
8	2.60	0.60	38.32	37.67	48.14	0.45	0.77
9	2.26	0.54	35.65	34.88	47.05	0.41	0.72
10	1.93	0.39	28.95	28.27	38.05	0.35	0.78
11	2.66	0.42	30.14	29.65	36.55	0.39	0.70
12	2.89	0.51	34.14	33.75	41.43	0.38	0.77
13	1.86	0.24	20.07	19.48	24.87	0.31	0.83
14	2.52	0.50	34.20	33.34	41.51	0.41	0.83
15	4.10	1.18	54.92	54.15	66.77	0.62	0.79

2. Kelly's Index (KI)

The concentration of Na^{+} measured against Ca2^{+} and Mg^{2+} is known as Kelly's ratio, based on which irrigation water can be rated (Kelly, 1946).

$$\boldsymbol{KI = \frac{Na}{(Ca+Mg)}} \ldots\ldots\ldots\ldots(3)$$

As per Kelly's ratio water are categorized into suitable, if KR < 1, marginal, when KR 1-2 and unsuitable if KR > 2. In the present study the KI values varied from 0.24 to 1.18. 94 % of the groundwater samples are suitable for irrigation with Kelly's ratio < 1.

3. Sodium Percentage (Na%)

The sodium content in irrigation water is usually expressed in Na%. It affects soil structure by exchange process of sodium in water for Ca^{2+} and Mg^{2+} in soil, which reduces soil permeability. To assess the suitability of water quality for irrigation, the percentage of sodium in water is calculated by the following equation (Wilcox, 1955):

$$Na\% = \frac{Na^{+}+K^{+}}{(Ca^{+}+Mg^{2+}Na^{+}+K^{+})}\cdot 100 \ \ldots\ldots(4)$$

Na%	excellent	0 - 20
	good	20 - 40
	permissible	40 - 60
	doubtful	60 - 80
	Unsuitable	>80

The calculated values of the sodium percentage Na% in the groundwater of the study area ranged from 20.07 % to 54.92%. 80 % of the samples from the study area are in the good category.

4. Soluble Sodium Percentage (SSP)

Wilcox has proposed a classification for rating irrigation waters on the basis of Soluble Sodium Percentage (SSP). The SSP was calculated using following formula (Wilcox 195):

$$\boldsymbol{SSP = \frac{Na}{Ca+Mg+Na} \times 100} \ \ldots\ldots\ldots\ldots(5)$$

The values of SSP < 50 indicate good quality of water, and higher values >50 show that the water is unsafe for irrigation [38]. In Table (2), 94% of groundwater samples show SSP values <50, that indicates good quality for irrigation.

5. Permeability Index (PI):

The PI in a groundwater sample measures the total concentration of Na and HCO_3 to the total cations. (Doneen, 1964) classified irrigation waters into three classes, Class I (>75 %), Class II (25-75 %) and Class III (<25 %). Permeability Index is calculated by using the following formula:

$$\boldsymbol{PI = \frac{Na+K+\sqrt{HCO_3}}{(Ca+Mg+Na+K)}\cdot 100} \ \ldots\ldots\ldots\ldots(6)$$

The permeability index of the study area ranges from 24.87 to 66.77%. All the samples are fall under Class II and indicating that the water is good for irrigation purposes, Table (2).

Standard diagrams such as Wilcox and Gibbs diagram were determined for the suitability of groundwater for irrigation.

6. Wilcox diagram

The plot of analytical data on the (Wilcox, 1955) diagram relating EC and Na% show that water samples fall in three classes, Figure (2). About 67% of the water samples are good to doubtful category for irrigation, and 33% fall under unsuitable for irrigation purposes.

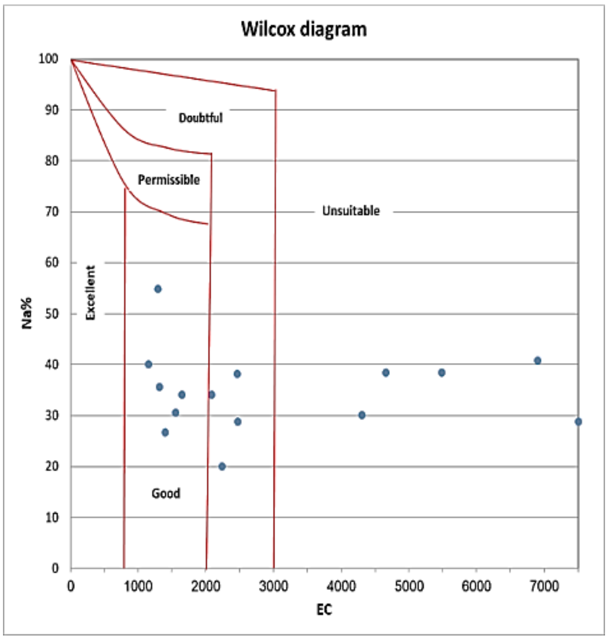

Figure (2): Wilcox diagram relating Sodium Percentage (Na%) and Electrical conductivity (EC).

7. Gibbs diagram

Gibbs diagram is employed to interpret the effect of hydro geochemical processes such as precipitation, rock-water interaction mechanism and evaporation on groundwater geochemistry. The reaction between groundwater and aquifer minerals has a considerable role in groundwater quality which is useful to assume the genesis of water. Gibbs ratio is calculated by using the following equations (Gibbs, 1970):

$$GR1 = \frac{Na^+ + K^+}{(Ca^+ + Na^+ + K^+)} \dots\dots\dots\dots (7)$$

$$GR2 = \frac{Cl^-}{(Cl^- + HCO_3^-)} \dots\dots\dots\dots (8)$$

In the present study, Gibbs ratio GR1 values varied from 0.31 to 0.62 and Gibbs ratio GR2 values varied from 0.61 to 0.90 (Table 2). According to Gibbs classification the majority of groundwater samples of the area on the plot TDS versus GR1 & GR2 (Figure 3a, b) are fall under evaporation dominance. Groundwater samples of the area on the plot Figure (3b) show similar variation with that of the cations diagram Figure (3a). However, the samples are shifted from right to left fields due to less Cl^- contain and high concentration $+HCO_3^-$.

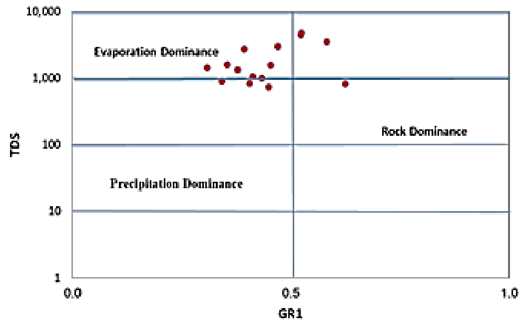

Figure (3a): Gibbs, TDS ver. Gibbs ratio GR1, Cations

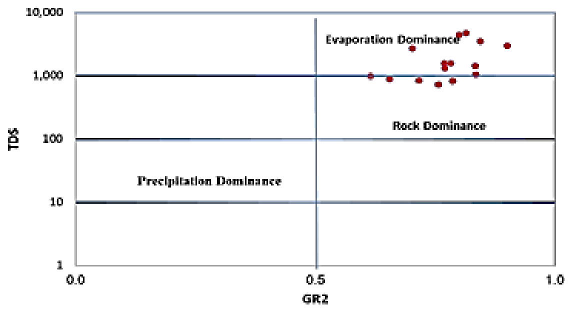

Figure (3b): Gibbs, TDS ver. Gibbs ratio GR2, Anions

CONCLUSION

Finally, it could be concluded that the irrigation water quality parameters indicated that the majority of the groundwater samples in Mitrid are suitable for irrigation purposes. The Gibbs diagram showing the hydrogeochemical characteristics is chiefly controlled by evaporation dominance followed by rock–water interaction process. The Na% and the resulting Wilcox diagram also classify the groundwater as good to doubtful category.

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