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APPLICATION OF WILCOX AND UNITED STATE SALINITY LABORATORY DIAGRAMS TO ASSESS GROUNDWATER QUALITY FOR IRRIGATION PURPOSES AROUND SAQLAWIYAH AREA, AL-ANBAR, IRAQ

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ABSTRACT

Wilcox and United State Salinity Laboratory (USSL) diagrams have been applied in the current study to evaluate the available water wells in the area surrounded Saqlawiyah town and to determine its suitability for agricultural purposes. To achieve this goal the Electrical Conductivity (EC) has been measured and Sodium Percent (Na%) and Sodium Adsorption Ratio (SAR) have been calculated based on the chemical analysis of Ca_2^{2+}, Mg^{2+}, Na^{+}, K^{+}. EC values show that 8.33% of the available water well falls in the tolerable class, 33.33% under intolerant class and 58% in health hazard class. The USSL diagrams show that (50%) of the available well water in the study area is not suitable for irrigation as it belongs to the very high salinity hazard category (C4). The remaining water well samples are belonging to high salinity hazard category (C3). According to the classification scheme of Wilcox irrigation water, the majority of the well water samples (about 50% of water samples) fall under unsuitable category and 41.66% under a doubtful to unsuitable category. Other percentage of the water samples, which represents that of well No. 12 fall within good to permissible category. Therefore only this water can be used for irrigation purposes in the study area. This is because the well lies near the river, where it may get a direct additional recharge.

تطبيق مخططات ويلكوكس ومختبر الملوحة الامريكية القياسية لتقييم المياه الجوفية لاغراض الري في المنطقة المحيطة بمدينة الصقلاوية في محافظة الانبار

مفيد سعدي الحديثي

المستخلص

تم تطبيق مخططات ولكوكس ومختبر الملوحة الامريكية القياسية في هذه الدراسه لغرض بيان إمكانية استخدام مياه الآبار الموجودة في المنطقة المحيطة بمدينة الصقلاوية في محافظة الأنبار في العراق لأغراض الري. ولتحقيق هذا الهدف تم قياس التوصيلية الكهربائية وحساب نسبة امتزاز الصوديوم (SAR) والنسبة المئويه للصوديوم (%Na) بناء على تحاليل كيميائيه مثل الكالسيوم والمغنيسيوم والصوديوم والبوتاسيوم. اعتمادا على قيم الإيصالية الكهربائية تبين ان 8.33% من مياه الآبار الموجوده في منطقة الدراسة مقبولة و33.33% غير مقبولة و 58% هي مضرة بالصحة. واعتمادا على

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مخطط الملوحة الامريكي القياسي تبين ان 50٪ من المياه غير صالحه والتي تقع في صنف الملوحة العالية جدا (C4) والمياة المتبقية تقع في صنف الملوحة العالية (C3) والتي من الممكن استخدامها لأغراض الري تحت ظروف خاصه. وبناءا على نظام تصنيف ولكوكس تبين ان معظم مياه الآبار لمنطقة الدراسة والتي تمثل نسبة 50% من مجموع عينات المياه هي غير ملائمة للري ونسبة 41.66% مشكوك فيها. أما النسب المتبقية من عينات المياه والتي تمثل البئر رقم 12 فتقع ضمن الفئة الجيدة والجائز استخدامها لأغراض الري في منطقة الدراسة بسبب وقوع هذا البئر بالقرب من النهر وبالتالي ربما يحصل على تغذية إضافية مباشرة.

INTRODUCTION

Groundwater is one of the most important sources of irrigation water supply for many areas in the world. Hence, groundwater evaluation for irrigation has become a necessary and important assignment for present and future groundwater quality management. In Iraq, river water is the main source for drinking, agriculture or any other purpose, but in recent times, river water faces a lot of problems, particularly the lack of rainfall, industrial and runoff pollution which affect the quality of waters. Hence, there is a need to look for other sources of water or emphasize water assessment of the existing wells. The present study has been taken up with an objective to assess twelve wells available in the area surrounding Saqlawiyah town for irrigation purposes. The water wells are considered the best source for irrigation and some time for drinking as it is believed to be safe and free of contaminants from suspended matter and pathogenic bacteria (Israil *et al*., 2006).

In the current study, Wilcox and USSL diagrams have been used to assess the groundwater quality for irrigation purposes. Various workers have applied Wilcox and United State Salinity laboratory (USSL) diagrams to assess the groundwater quality for irrigation purposes. Saumitra *et al*. (2013) have assessed the suitability of groundwater for drinking and agricultural purposes in the south 24-Parganas district of west Bengal in India using the Wilcox and US salinity diagrams and concluded that 46% of the water samples fall under good to permissible category and 37% under the permissible to doubtful. Sadashivaiah *et al*., (2008) evaluated the suitability of water for irrigation using Sodium Adsorption Ratio, Residual Sodium Carbonate, Sodium Percentage, Salinity Hazard and USSL diagram. This study shows that most of the water samples in Tumkur, Taluk fall in the suitable range for irrigation purpose from USSL diagrams and fall in the suitable range for irrigation purpose either from SAR, % Na or RSC values. Khodapanah *at al*. (2009) have also used chemical indices such as percentage sodium, Sodium Adsorption Ratio (SAR), Wilcox diagram and Salinity diagram to evaluate the suitability of water for irrigation. Belkhiri *et al*. (2010) have used hydrochemistry of groundwater in Ain Azel plain, Algeria to assess the quality of groundwater for determining its suitability for drinking and agricultural purposes. In this study the USSL diagram illustrates that most of the samples fall in (C3 – S1) quality with high salinity hazard and low sodium hazard. Fipps (2003) and Hakim *et al*. (2009) present geochemical data in the form of graphical charts such as the USSL and Wilcox diagrams to assess the quality of groundwater.

The present study is made with the objective of assessing the available water wells for irrigation purposes around Saqlawiyah by the application of Wilcox and USSL standard diagrams.

- **Geology and Location of the Study Area**

The study area lies on the eastern margin of the Inner (Stable) platform of the Arabian Plate (Fouad, 2010). It is covered mostly by Quateernary sediments of the Mesopotamia Plain with local exposure of late Neogene Formations such as: Injana and Fatha formations

(Yacoub and Dikran, 1993) (Sissakian and Salih, 1995). The Quaternary unconsolidated sediments consist mainly of river sediments of fine to medium gravel and colored sand overlapped by silt and clay. No tectonic effects are present as seen by the absence of folds and faults. Due to high evaporation rates and low permeability of the upper layers and the lack of adequate amount of rain, the water quality is suitable for specific uses only (Ministry of Irrigation, 1982). The main aquifer is the sand and gravel, as well as the sandstone (Hussein, 1983). The well water level in the study area has different depths ranging from 10 meter to 30 meter as shown in Table 1.

The area lies between 33° 22' 22" to 33° 26' 26" N and 43° 36' 36" to 43° 42' 42" E. It covers an area of approximately 116 Km^2 (Fig.1). There are 12 water wells in the study area selected for the purpose of conducting the current study. The climate is hot in summer and cool, rainy in the winter. High percentage of available cultivated areas can be used for agriculture whereas only 15% of the total geographical area is under irrigation. Palm trees and many kinds of fruit and vegetable is the main crop.

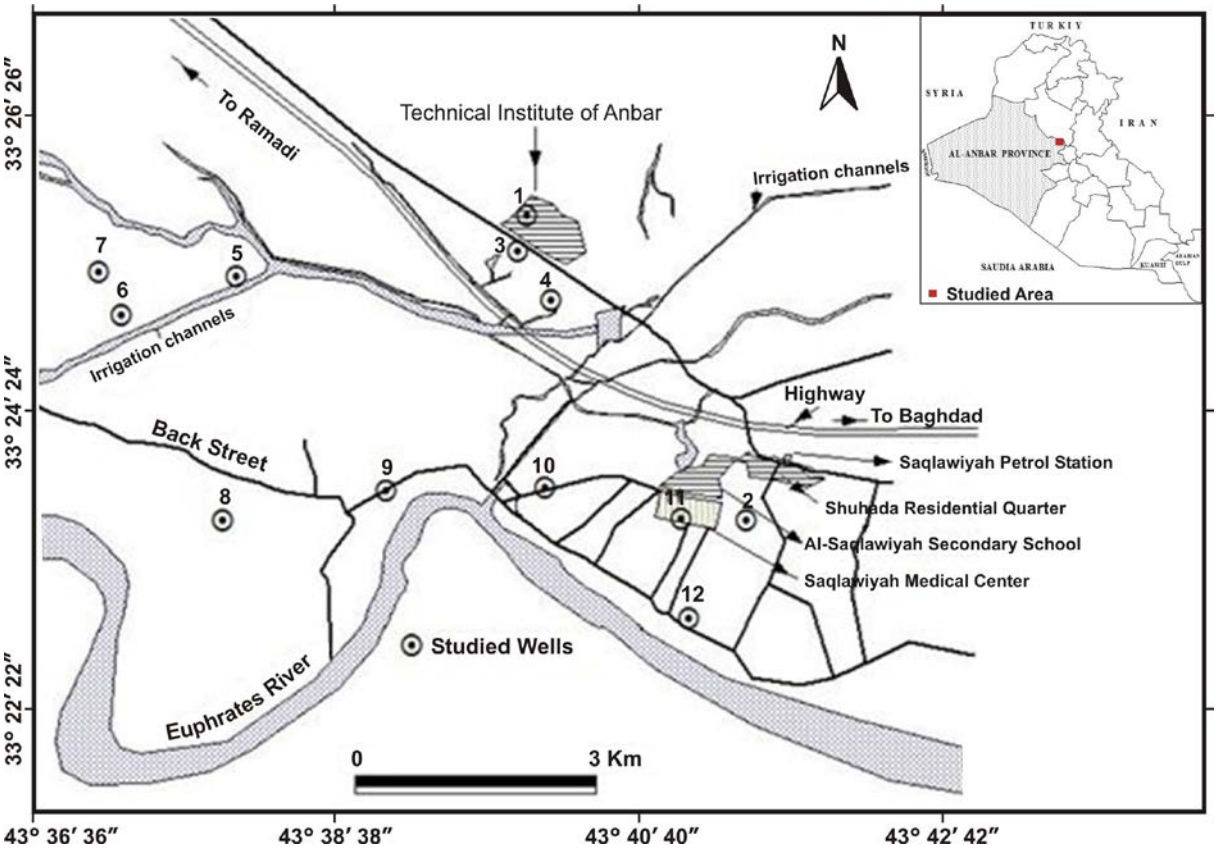

Fig.1: Location map of the study area showing studied wells

METHODOLOGY

The samples were collected from 12 wells in the region during the months (July 2012, October 2012 and January 2013). The samples were analyzed for chemical parameters such as Ca_2^{2+}, Mg^{2+}, Na^{+}, K^{+} and the Electrical Conductivity (EC) is measured using standard procedures. Only the average of the measured values for the three months is taken due to lack of significant differences between them and no effect of the rain is noticed on the water quality. The average of measured values of groundwater samples is summarized in Table 1

and their locations are shown in Figure1. Conductivity meter has been used to measure the Electrical Conductivity in the field. Calcium, sodium and potassium have been analyzed using flame photometer and the Magnesium ions analysis is made by EDTA titration method.

For the purpose of groundwater assessment and their suitability for irrigation, many parameters are taken into account such as Alkalinity, Salinity and Toxicity (Shainberg and Oster, 1976) and (Todd, 1980). Electrical Conductivity, Permeability Index (Doneen, 1964) are also used. Toxicity is caused by Sodium Absorption Ratio (SAR) which has caused many problems in the relationships of soil, water and plant. In the current study the most important factors taken into account are:

- Electrical Conductivity
- Sodium Adsorption Ratio (SAR).
- Percentage of Sodium (% Na)

The Electrical Conductivity has been measured in the field and the measured values are presented in Table 1. The SAR and Na% values were obtained from the following equations and its values also presented in Table 1.

$$SAR = Na^{+} / [(Ca^{2+} + Mg^{2+}) / 2]^{0.5} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

$$\% Na = (Na^{+} + K^{+}) / (Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

The calculated data were plotted on standard diagrams (USSL, 1954 and Wilcox, 1955) to assess the water quality.

Table 1: Average measured values of chemical parameters of groundwater Samples in the study area

Parameter	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6	Well 7	Well 8	Well 9	Well 10	Well 11	Well 12
EC (µS/cm)	4057	4893	3212	3916	4173	3799	2427	2928	2363	2016	2142	1528
Ca^{2+} (meq/l)	20	21	21	15	16	15	9	13	10	11	8	7
Mg^{2+} (meq/l)	24	25	17	23	25	25	15	22	17	8	8	8
K^{+} (meq/l)	0.65	0.69	0.64	0.2	0.18	0.17	0.18	0.52	0.16	0.24	0.19	0.16
Na^{+} (meq/l)	33	37	16	21	25	24	14	20	12	12	7	8
SAR	7.0	7.7	3.6	4.8	5.4	5.3	3.9	4.9	3.3	3.8	2.5	2.8
% Na	43.2	44.9	29.6	35.8	37.6	37.8	36.6	37.5	31.2	39.0	30.9	34.1
Depth (m)	11	11	12	12	11	12	13	13	14	15	15	30

RESULTS AND DISCUSSION

- **Alkalinity Hazard**

Alkali hazard of the irrigation water is estimated by the complete and qualified concentration of cations which is usually expressed as a sodium adsorption ratio (SAR). Figure (2) and Table (1) show the calculated values of SAR for all wells showing a range from (2.5 to 7.7).

- **Salinity Hazard**

Electric Conductivity provides adequate estimate of the salinity hazard on agricultural crops because it reflects the amount of total dissolved salts in the water. As indicated in

Figure (3) the values of Electrical Conductivity of groundwater in the studied wells vary between (1541 to 4517). The EC values of all studied wells indicate that they are unsuitable for irrigation according to Wilcox classification except well number (12) due to additional recharge of fresh water directly from the river which contributes to reducing the salinity. Depending on EC classification, as indicated in Table (2), 8.33% of the available water well falls in the tolerable, 33.33% fall within the intolerable and 58% in the health hazard categories.

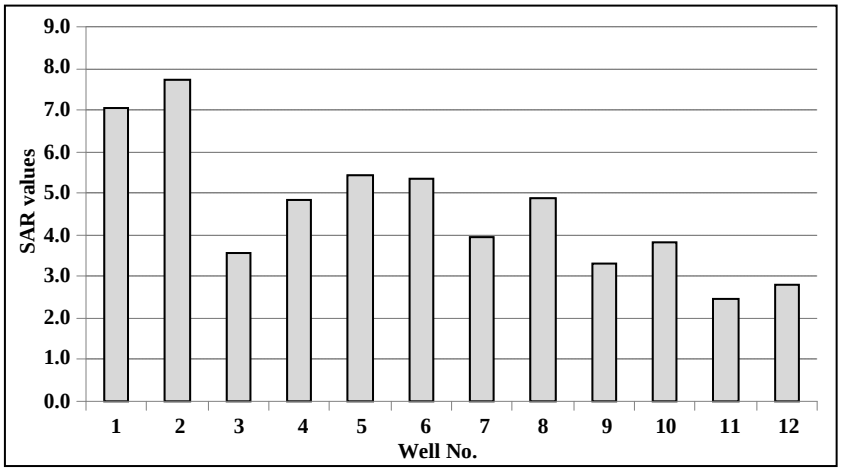

Fig.2: Values of SAR for all studied wells

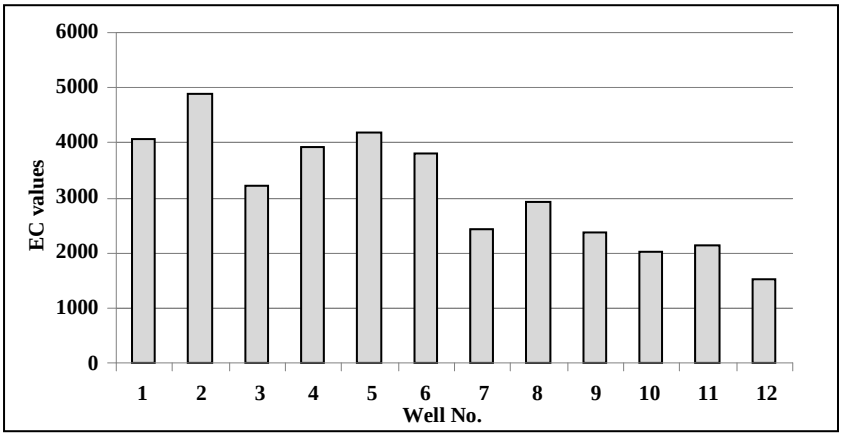

Fig.3: Values of EC for all studied wells

Table 2: EC (µS/cm) Classification of Groundwater (Wilcox, 1955)

Conductivity range (Wilcox, 1955)	Quality	Well No.	Percentage of sample In the study area
< 1000	Safe	Nil	Zero
1000 – 1500	Tolerable	12	8.33%
1500 – 2000	Tolerable to some extent	Nil	Zero
2000 – 2500	Intolerable	7, 9, 10 and11	33.33%
> 2500	Health Hazard	1, 2, 3, 4, 5, 6 and 8	58.33%

- **Sodium Percentage (Na %)**

Irrigation water that contains a high percentage of sodium will raise the exchange of sodium content in the soil, which affects the soil texture and its permeability. This makes it difficult to plow the soil and is not valid for the emergence of seeds (Triwedy and Goel, 1984). If the sodium content is high in the irrigation water, Ca^{2+} and Mg^{2+} magnesium and calcium exchange with Na^{+}; accordingly it causes permeability and impairment of the filth of soils (Karanth, 1987). Also the water is considered unsuitable for irrigation if the percentage of sodium is more than 60%. In the study area the percentage of sodium ranges from 30% in well number (3) to 45% in well number (2) as shown in Figure (4).

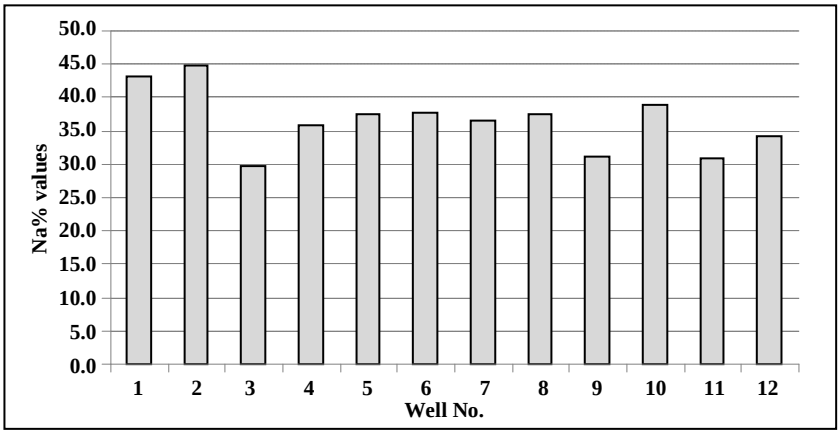

Fig.4: Values of Na% for all studied wells

- **USSL and Wilcox Diagrams**

To assess the suitability of well water in the study area for irrigation purposes, more detailed analysis have been conducted by plotting analytical data on USSL and Wilcox diagrams as shown in Figures (5) and (6) respectively.

In the USSL diagram the conductivity (EC) has been taken as salinity hazard and (SAR) as the alkalinity hazard. The measured EC values of the well water in the current study range from 1528 – 4893 µS/cm. The high concentration of salinity content might be due to the geological formations of the area where rain water washes the soil and releases the salt as well as the domestic and fertilizers to the groundwater. Through USSL diagram, it is noted that a high percentage (50%) of water is not suitable for irrigation and belong to the very high salinity hazard category (C4). Samples from the remaining water wells belong to high salinity hazard as shown in Figure (5).

Based on the classification scheme of Wilcox for irrigation water, the majority of the well water samples (50%) fall under unsuitable category and (41.66%) under the doubtful to unsuitable category. Only one well falls under good to permissible category because of the occurrence of this well near the river and being deeper than other wells, hence it gets a direct additional recharge.

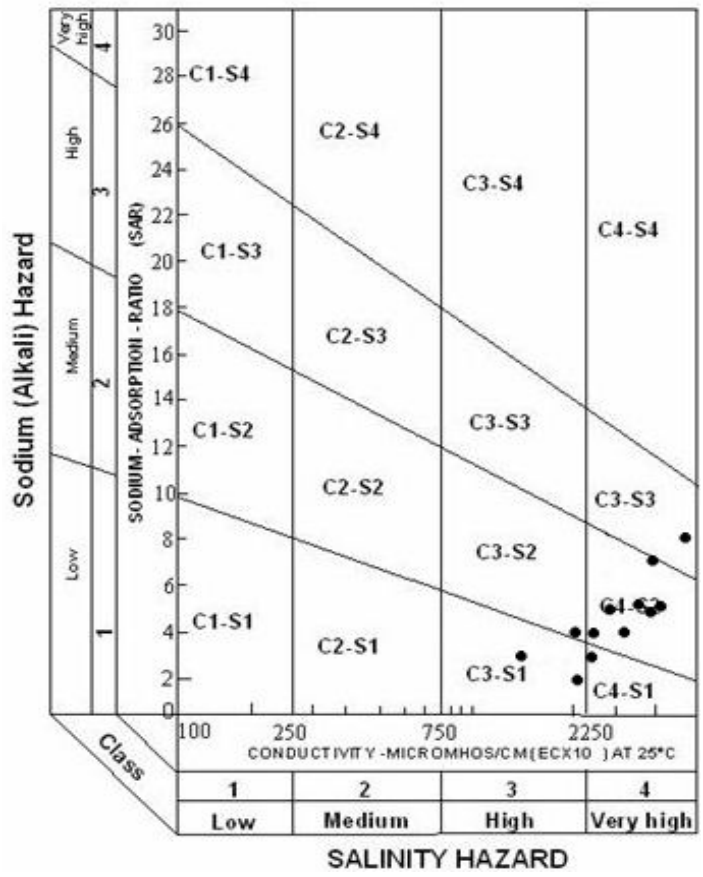

Fig.5: Diagram for irrigation water quality classification (USSL, 1954)

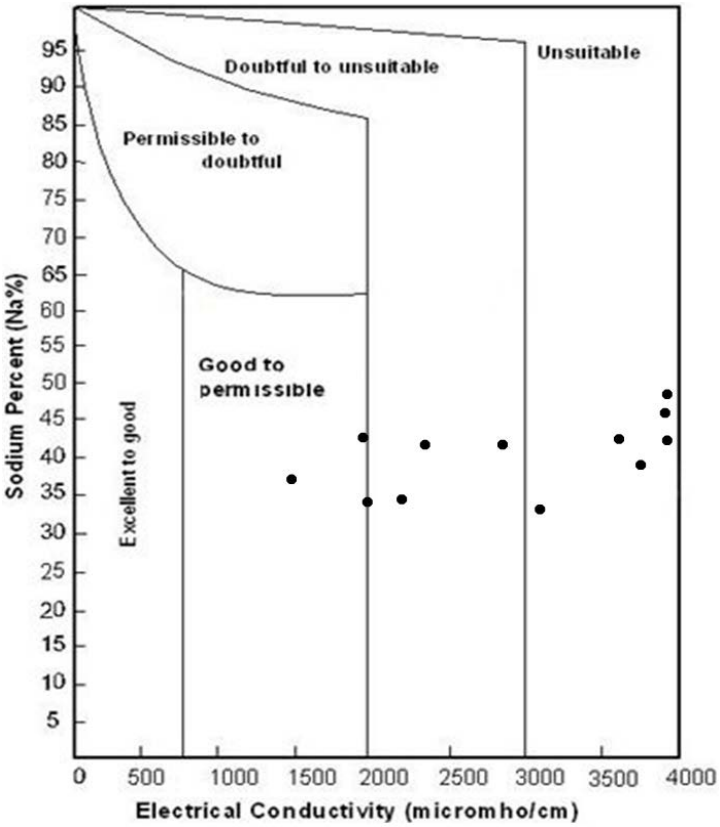

Fig.6: Diagram for irrigation water quality classification (Wilcox, 1955)

CONCLUSIONS

To classify the quality of available well waters around the area of Saqlawiyah town into different categories for the irrigation purposes, three factors have been used such as EC, Sodium percentage (Na%) and Sodium Adsorption Ratio (SAR). The data are plotted on Wilcox and United State Salinity Laboratory (USSL) diagrams. The results show that the water qualities in the study area are unsuitable for irrigation purposes. At one site (well number 12) which gets additional recharge, the water quality is good to permissible and can be used for irrigation purposes.

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