MONITORING SEASONAL VARIATION IN GROUND WATER QUALITY AND EVALUATION OF ITS SUITABILITY FOR IRRIGATION IN THE NIMRUD AREA SOUTH – EAST OF MOSUL – IRAQ

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ABSTRACT

Sixteen water wells have been chosen in different locations within Nimrud district, to study the variation of ground water quality during the dry and the wet season. Analysis including salinity, pH, temperature, total hardness, major cations and anions were performed. Ground water salinity (EC) has significant variation and ranged from (0.81 to 5.82) and (0.88 to 5.77) ds m⁻¹ in dry and wet seasons respectively. About 75% of water samples have a higher EC in the wet season compared with the dry season. All samples are very hard water class. Half of the wells have higher calcium and chloride concentration in the wet season than in the dry season. Two third of samples have higher Magnesium in the dry season than the wet season. Around 87% of wells have higher sodium and potassium in the wet season than dry season. About three quarters of wells have a higher sulphate in the wet season compared with the dry season. About 80% of samples have a higher nitrate concentration in the dry season compared to the wet season. Water quality for irrigation has been evaluated using several parameters. All samples fall into three category groups, C₄S₁, C₄S₂ and C₃S₁ according to the US salinity diagram.

INTRODUCTION

Recently Iraq is facing a shortage in rainfall, long periods of drought, and a decline of water supplies, as a result of climate changes and dropping of rivers discharge from upstream countries like Turkey and Iran. Therefore, many farmers use ground water as an alternative to surface water, even if ground water is brackish and not fresh water, which has a detrimental effect on soil properties and plants. There are two types of soil salinity, primary and secondary (Hopmans et al., 2021). The first type occurs as a result of geological factors (natural) like kinds of rocks/ minerals which are highly dissolved in water. The second type comes from human activity like the use of saline ground water for irrigation, or extensive use of chemical fertilizers in order to increase agricultural production (Knapp and Baerenklau, 2006). That leads to the deterioration of soil quality and its fertility (King and David, 2014). Periodically use of brackish ground water without leaching these salts via rainfall or fresh water. That leads to speeding up the secondary salinity processing which has a negative impact on soil, such as decline of hydraulic conductivity, destroy soil structure, drop of infiltration and forming of soil crust which prevent seeds germination (Al-Zu’bi, 2007). Getting data about ground water quality gives us
significant information about the nature of aquifers and the geochemical processing that takes place in subsurface environments (Raju et al., 2011). AL-Saffawi et al., (2022) studied the ground water quality in groups of wells within Nimrud area, and find out around 70% of water wells were not fit for animals drinking like cattle and poultry, due to the effect of geological formation on ground water quality. The aim of this research is to identify the spatial and temporal variation in ground water quality between the wet and dry seasons within the study area to evaluate its quality for irrigation purposes, for better management and sustainability of this precious water resource.

MATERIALS AND METHODS

The field work was included collection 36 water samples, from 16 water wells, sixteen samples from the dry season (October 2021) and the rest from the wet season (April 2022), see (Figure 1). All samples collected after ten minutes of pumping from each well. The information about wells are listed in table 1. Temperature is measured using mercury thermometer. EC, pH and TDS are measured in the field using EC-pH meter. Calcium, magnesium, chloride, carbonate, bicarbonate and total hardness are measured using titration method. Sodium and potassium are measured using flamephotometer. Finally sulphate, nitrate and phosphate are measured using spectrophotometer method. All chemical analysis were carried out using standard methods.

Figure (1): location map of the study wells.
Table (1): Name, coordination and some information about the study wells.

<table>
<thead>
<tr>
<th>Well NO.</th>
<th>Name/Village</th>
<th>Depth (m)</th>
<th>Static Water table (m)</th>
<th>Coordinates</th>
<th>Usage</th>
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**RESULTS AND DISCUSSION**

**Temperature:**

The ground water temperature ranged from 24.3 to 28 °C, with average 25.7 °C in the dry season, while it ranged from 23.5 to 26.4 °C, with average 25.4 °C in wet season, table (2). The comparison between two seasons revealed that all values are closed to each other and almost constant in both seasons (figure 2). The maximum different in temperature between two season not exceed 2.4 °C. That is a very slight variation of ground water temperature belonged to it is far away from the direct effect of atmosphere and other climatic factors such as surface water (Effendi and wardinato, 2015). These results slightly lower than results obtained by (AL-Saffawi et al., 2022), which ranged from 19.3 to 22 °C may be that belonge to the different in the season of collection samples for each study.

**pH:**

The pH ranged from 7.3 to 7.9 in dry season, while it ranged from 6.4 to 7.9 in wet season, table (2). The majority of water samples have neutral or slightly alkaline water because the abundant of carbonate minerals in rocks and soils. As we
can see from the (figure 2) the majority of water samples have higher pH in dry season in compare with wet season.

**Water salinity:**

The EC values ranged from 0.81 in well No. 15, to 5.82 in well No. 2, with averaged 2.66 ds.m$^{-1}$ in dry season, while it values vary from 0.88 in well No. 15 to 5.77 in well No. 1, with averaged 2.43 ds.m$^{-1}$ in wet season, table (2). There are significant variations of water salinity (EC) among samples, because the effect of rocks, sediments and minerals type within the aquifers, if ground water moves via geological layers which is rich with evaporates rocks like gypsum and anhydrite, then the water have higher salinity level. While water extraction from quaternary deposits which is rich with siltstone, sandstone and gravel has fresh water and it is poor of total dissolved salts, that means lower EC (Al-saffawi and Al-Sardar, 2018 and Ameloko et al., 2018). These results are consistency with (AL-Saffawi et al., 2022), it ranged from (1.8- 5.06) ds.m$^{-1}$. (figure 3) showed that wells No (2,6,10 and 12) have higher EC in dry season in compare with wet season. The rest wells have higher EC in wet season than dry season, may be caused by the sequence of drought, without recent recharge to the aquifers via rainfall to dilute salinity of ground water, and there is an extreme scare of rainfall during the year 2021-2022. The TDS varied from 403 to 2908, with average 1332 ppm in dry season, while it varies from 438 to 2887, with average 1241 ppm in wet season. As we know the TDS can be used as alternative to the EC. According (Freeze and Cherry, 1979) around 50 percentage of samples fall in fresh water class (TDS less than 1000 ppm), while the rest of samples fall under brackish water class (TDS range from 1000 to 10000 ppm).

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<th>TDS ppm</th>
<th>TH °C</th>
<th>Temp. °C</th>
<th>pH</th>
<th>EC dS m$^{-1}$</th>
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<td>382</td>
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<td>5.77</td>
<td>2887</td>
<td>1862</td>
<td>26.4</td>
</tr>
</tbody>
</table>
Mean & 7.6 & 2.663 & 1332 & 975 & 25.79 & 7.0 & 2.43 & 1241 & 1012 & 25.49 \\
SD & 0.6 & 1.650 & 824.1 & 406.0 & 0.821 & 0.3 & 1.340 & 686.2 & 377.9 & 0.816 \\
C.V & 7.89 & 61.96 & 61.86 & 41.64 & 3.18 & 4.8 & 55.14 & 55.29 & 37.34 & 3.20 \\

**Total Hardness:**

Total hardness (TH) ranged from 382 in well No. 15 to 1709 in well No.2, with average 975 ppm in dry season. In compare with wet season the total hardness ranged from 505 in well No.7 to 1862 in well No.1, with average 1012 ppm, table (2). About 68% of water wells have higher TH in wet season in compare with dry season. Just wells No. (2,6,7,11,12 and 16) have higher TH in dry season in compare with wet season, (figure 4). The maxium different between two season reach to 455 ppm in well No.3. All water samples have been classified as very hard water (TH > 300 ppm), because the dissolution and hydrolois of evaporate minerals such as gypsum, anhydrite and carbonate minerals like calcite,argonite and dolomite , which is considerd the main reason of water harndess (Bouderbala, 2017).

![Figure (2): variation of ground water temperture and pH in both seasons.](image)

![Figure (3): variation of ground water salinity in both seasons.](image)
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Figure (4): Variation of total hardness of groundwater in both seasons.

Cations:

Calcium concentration ranged from 74.2 in well No.15 to 388 in well No.1, with averaged 182 ppm in dry season, while it ranged from 89 in well No.15 to 345 in well No.1, with average 184 ppm in wet season, table (3) and (4). These results are consiststly with (Al-Obaidi, 2019), which was studied the water wells in the west bank of Tigiris river in Mosul city and it ranged from (86 to 474) ppm and (122 to 564) ppm in dry and wet season respectively. Around more than half samples (56%) the calcium content is high in wet season in compare with dry season, see figure(5).

Magnesium concentration ranged from 48.5 in well No.15, to 264 in well No.2, with averaged 128 ppm in dry season, while it ranged from 61 in well No.7, to 264 in well No.1, with average 135.9 ppm in wet season, these range slightly lower than ranged got by (Al-Obaidi, 2019) who studied the ground water quality in Mosul city. About two thirds of studied wells have higher content of magnesium in wet season in compare with dry season (figure 5). The elevation concentration of Magnesium and calcium in ground water come from to the dissolution of calcite, dolomite and gypsum minerals (Bouderbala, 2017). Theses minerals are abundant in the geological formation (Fatha formation) in the study area. Sodium concentration varies from 31 in well No. 11 to 385 in well No.2, with averge 135 ppm in dry season. In the other hand it conconcentration varied from 18.5 in well No.3 to 399 in well No.2 with average 169.8 ppm in wet season. These results are lower than the ranged obtian by (AL-Saffawi et al., 2022), which ranged from 109 to 664 ppm. The reason for that belong to the different in lithology and depth of wells. Around 87% of studied wells have higher sodium content in wet season in compare with dry season. In general the concentration of sodium in ground water is not high in the studied wells. Postasium concentration ranged from 1.4 in well No. 4 to 15.3 in well No. 2, with average 3.2 ppm in dry season. while in wet season it ranged from 0.55 to 9.35, with average 2.05 ppm. The concentration of potassium in all wells are higher in dry season than wet season except wells No. 6, figure 6. The low concentration of potassium in ground water as a result of high ability of clay minerals to sorption dissolved potassium, which leads to drop its concentration significantly in ground water (Ibrahim and Nofal, 2020 and Ganiyu et al., 2018).

Anions:

Chloride concentration ranged from 42.6 in well No. 15 to 355 in well No.2, with averaged 135.4 ppm in dry season. In the other hand it concentration ranged from 24.8 in well No. 3 to 414 in well No.2, with average 122.1 ppm in wet season table (3),(4), theses ranges are higher that range got by (Al-Obaidi, 2019) in dry and
wet season. Fifty percentage of studied wells have higher chloride concentration in dry season than wet season figure(7). These fluctuation of chloride is due to the variation of geological formation, or may be come from domestic waste water which is polluted shallow ground water (Danhalihu., et al 2018). Sulphate concentration ranged from 165 in well No. 15 to 1645 in well No.2, with averaged 733.6 ppm in dry season. While it concentration ranged from 419 in well No. 15 to 1497 in well No.1, with average 854 ppm in wet season. These results are similar to the range got by ( Al-Aarajy, 2022) in dry season while our results are higher than the range got from ( Al-Aarajy, 2022) in wet season, may be the reason for that there is no rainfall took place during this season (dry year). About three- quarter of studied wells have higher concentration in wet season than dry season, (figure 7). Sulphate is the domination anions, and it concentration is extremely high because the dissolution of gypsum and anhydrite minerals .

Table (3): Major cation and anions concentration in dry season.

<table>
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<tr>
<th>Sample No.</th>
<th>Ca(^{2+})</th>
<th>Mg(^{2+})</th>
<th>Na(^{+1})</th>
<th>K(^{+1})</th>
<th>Cl(^{-})</th>
<th>SO(_4)(^{2-})</th>
<th>HCO(_3)(^{-})</th>
<th>NO(_3)(^{-})</th>
<th>PO(_4)(^{3-})</th>
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</table>

Carbonate CO$_3^{2-}$ not detect during the chemical analysis, (Freeze and Cherry, 1979) point out at pH level below 8.2, carbonation (CO$_3^{2-}$) combination with hydrogen(H$^+$) to form bicarbonate( HCO$_3^{-}$), all the water samples have pH not exceed 7.9 in both season, that reason why not recording any concentration. Bicarbonate concentration ranged from 134 in well No. 5 to 384.3 in well No .8, with averaged 249 ppm in dry season. while it concentration ranged from 53.2 in well No. 7 to 376 in well No.2, with average 144 ppm in wet season. Except wells No. 1, 2 and 5, all the water samples have higher concentration of bicarbonate in dry season than wet season (figure 8). The main sources of bicarbonate are come from carbonate minerals, as well as may be from oxidation of organic water in the rhizospheres zone and from agricultural activity, furthermore may be come from the combination of carbon dioxide (CO$_2$) with water during the hydrological cycle (Freez and Cherry, 1979). Nitrate concentration ranged from 5.9 in well No. 3 to 41.3 in well No.1, with averaged 31.6 ppm in dry season. while it concentration ranged from 19.4 in well No. 5 to 42.5 in well No.13, with average 34.6 ppm in wet season, (figure 8). These results that are within the same range which got by (Al-Aarajy, 2022) in dry and wet season. Some wells are contamination with nitrate as a results of agricultural activities and intensive use of fertilizers in term of using this water for drinking purpose. About 70 % of water samples have higher nitrate concentration in wet season than dry season. Finally Phosphate concentration ranged from 0.81 in well No.10 to 10.2 in
well No.1, with average 3.3 ppm in dry season. while it concentration ranged from 0.55 in well No. 1 to 2.1 in well No.16, with average 1.5 ppm in wet season (figure 9). About 70% of water samples have higher phosphate concentration in dry season than wet season. Phosphate content in ground water is relatively low because it has a high ability of clay and some organic compounds to adsorption it, that lead to drop it concentration significantly (Karsa and Houston, 2006).

Figure (5): variation of calcium and magnesium in both seasons.

Figure (6): variation of sodium and potassium in both seasons.

Figure (7): variation of chloride and sulphate in both seasons.
The variation coefficient :-

The coefficient of variance CV has been calculated according to the following equation:

\[ CV = \frac{SD}{m} \times 100 \]

CV = variation Coefficient, SD = standard Deviation, m = mean

If the value is less than 50%, that indicates the variable is homogenous, and the values are close to each other and not variable too much. However, if the value is more than 50%, that indicates the result have wide range and heterogeneous (Macko, 1994). (figure 10) showed the plot of CV% against all variables. Results were divided into two groups. Group one have CV% values less than 50 percentage, which included pH, temperature, total hardness, calcium, magnesium, and Nitrate. Just bicarbonate in dry season, sulphate and phosphate in wet season. Second group which have CV% values greater than 50 percentage, which included EC, TDS, sodium, potassium, and chloride. Just sulphate and phosphate in dry season, and finally bicarbonate in wet season. The higher value of CV% for some parameters like EC and TDS, give us an indicator that most wells are penetration more than one aquifer, which lead to mix fresh water with saline water and give us wide variation of water salinity.
**Evaluation of ground water for irrigation:**

Several parameters have been used to assessment of ground water for agricultural such as Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC), Potential Salinity (P.S), Magnesium hazard (MH), Permeability index (P.I) and Kelly ratio (KR), table (5) explain the details.

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<th>Variables</th>
<th>Equation</th>
<th>Source</th>
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<td>Potential salinity (P.S)</td>
<td>[P.S = Cl + \frac{1}{2}SO_4]</td>
<td>Delgado et al (2010)</td>
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<td>Sodium Adsorption Ratio (SAR)</td>
<td>[SAR = \frac{Na}{\sqrt{Ca + Mg}}]</td>
<td>(Wilcox, 1955)</td>
</tr>
<tr>
<td>Permeability index (PI)</td>
<td>[PI = \left(\frac{Na + \sqrt{HCO_3^-}}{Na + Mg + Ca}\right) \times 100]</td>
<td>(Donnen, 1964)</td>
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<td>Residual Sodium Carbonate (RSC)</td>
<td>[RSC = [(HCO_3^- + CO_3^{2-}) - (Ca^{+2} + Mg^{+2})]]</td>
<td>(Eaton, 1950)</td>
</tr>
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<td>Kelley ratio (KR)</td>
<td>[KR = \frac{Na^+}{Ca^{2+} + Mg^{2+}}]</td>
<td>(Kelly, 1940)</td>
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<tr>
<td>Magnesium hazard (MH)</td>
<td>[MH = \frac{Mg^{+2}}{Ca^{+2} + Mg^{+2}} \times 100]</td>
<td>Szabolcs &amp; Darab (1964)</td>
</tr>
</tbody>
</table>

SAR ranged from (0.47 to 4.02) with average 1.76 in dry season. In wet season it ranged from (0.22 – 4.16), with average 2.25. These results slightly higher than the ranged obtained by (Al-Hamdany, 2020), which various from 0.2 -1.25. The reason of low SAR values as a result of high concentration of calcium and magnesium in compare with sodium in ground water (Adejumo et al., 2018). According to SAR classification for irrigation, all water samples belonge to S\(_1\) class, which is indicate low sodium hazard, without negative impact on the soil infiltration and destroy soil structure because it high content of sodium (Nag and Das, 2014). Potential salinity ranged from (2.92-27.2) and (5.74-25.07) meq l\(^{-1}\) in dry and wet season respectively. RSC ranged from ( -31.24 to -3.01) meq l\(^{-1}\) in dry season, while it ranged from ( -
32.04 to -8.8) in wet season. All the results have negative values because the concentration of Ca and Mg are higher than carbonate and bicarbonate, that is not lead to dominate of sodium ion in soil solution (Eruola et al., 2020). These ranged are similar to the ranged of study carried out by (Al-Hamdany, 2020). All the values are suitable for irrigation according to this parameter. Permeability index ranged from (18.4 to 43.08)% with average 30.4 % in dry season. While it ranged from (7.08 to 42.6%), with average 30.91 in wet season. All water samples fall in the class I, as we can see from (figure 11), which indicate good water quality for irrigation in term of it effect on soil infiltration (Nag and Das, 2014). Magnesium hazard ranged from (36.8 to 74.32) %, with average 53.5 % in dry season. While it ranged from (41.7 to 74.8 %), with average 54.8 %, in wet season. If MH >50 % water is classification not suitable for irrigation (Szabolcs and Darab, 1964). About two–third of water samples are not fit for irrigation according to this parameter. Kelley ratio ranged from (0.08 to 0.48), with average 0.28 in dry season. While it ranged from (0.03 to 0.6), with average 0.36 %, in wet season. These results are agree with the results obtained by (Al-Hamdany, 2020), which it ranged from (0.01 to 0.35). If KR greater than one, water is considered not suitable for irrigation. All the results have KR values lower than 1 (see table 6) in both seasons, therefore all ground water samples are fit for irrigation crops and vegetables (Moghimi, 2016).

Table (6): Parameters for assessment of ground water for irrigation in both seasons.

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<td>18.45</td>
<td>56.30</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>Wet</td>
<td>8.69</td>
<td>1.78</td>
<td>-14.91</td>
<td>28.44</td>
<td>56.40</td>
<td>0.32</td>
</tr>
<tr>
<td>12</td>
<td>Dry</td>
<td>17.68</td>
<td>2.12</td>
<td>-30.19</td>
<td>24.89</td>
<td>50.13</td>
<td>0.26</td>
</tr>
<tr>
<td></td>
<td>Wet</td>
<td>15.65</td>
<td>2.76</td>
<td>-23.45</td>
<td>31.94</td>
<td>47.45</td>
<td>0.38</td>
</tr>
<tr>
<td>13</td>
<td>Dry</td>
<td>13.30</td>
<td>1.33</td>
<td>-18.53</td>
<td>23.36</td>
<td>74.32</td>
<td>0.20</td>
</tr>
</tbody>
</table>
The plot of SAR against EC, which represent wilcox diagram (wilcox, 1955), according to US Salinity laboratory guideline, see (figure 12). The results revealed that well No. 1 and 2 fall in the class C₄S₂, which is indicate a very high salinity hazard and medium sodium hazard. In the other hand well No. 6, 8, 12, 13 and 14 fall in the class C₄S₁ which is a very high salinity hazard and low sodium hazard. The rest of wells which represented more than 56 % of studied wells fall in the class C₃S₁, which means a high salinity and low sodium hazard.
CONCLUSION

There is significant variation of majority of variable in ground water samples between dry and wet season. The number of wells which have lower concentrations in the dry season compared to the wet season are; for salinity (6), water hardness (3) and pH (1) out of 16 wells. For cations the number of wells which have lower concentrations in the dry season than the wet season are: Calcium (7), Magnesium (6), sodium (2) and potassium (All). For anions the number of wells which have lower concentration in the dry season compared to the wet season are: chloride (8), nitrate (5), phosphate (5), sulphate (4) and bicarbonate (3). According to (FAO) and based on average water salinity in both season, three-quarter of studied wells are fit for irrigation, while the rest of wells are not suitable for irrigation. There no risk of present of sodium in water in term of SAR, which it effect on soil in negative way. We recommended to use water wells for agricultural crops that have medium to high tolerant to salinity, with continue leaching of salts from soil surface to avoid build up of soil salinity and degradation it over time. The sequence of recent drought lead to drop water level and depletion of ground water storage and deteriorate it quality. Management of ground water is considered top priority in term of quantity and quality in order to preserves and sustainability this precise water resources for next generation.

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CONFLICT OF INTEREST

None of the authors has a financial or personal relationship with other people or organizations that could inappropriately influence or bias the content of the paper.
مراقبة التغيير الموسمي في نوعية المياه الجوفية وتقييمها لاغراض الري في منطقة النمرود جنوب شرق الموصل – العراق

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الخلاصة

تم اختيار ستة عشر بئراً موزعة في مواقع مختلفة ضمن ناحية النمرود لدراسة نوعية المياه الجوفية خلال الموسمين الجاف والرطب ومراقبة تغايرها. شملت التحاليل كلًا من الملوحة، الدالة الحامضية، درجة الحرارة، العسرة الكلية، وتركيزات اليونات الرئيسية الموجبة والسالبة في المياه. كان تغاير ملوحة المياه الجوفية كبير وتمتراوح بين (0.81-5.82 ديسينتر م-1) في الموسم الجاف والرطب على التوالي. حوالي 75% من النماذج كانت ملوحتها أعلى في الموسم الرطب مقارنة بالموسم الجاف. جميع العينات كانت ذات عسرة مياه عالية جداً. نصف الآبار المدروسة كانت تركيزات كل من الكالسيوم والكلوريد أعلى في موسم الرطب مقارنة بالموسم الجاف. حوالي 87% من الآبار كان تركز كل من الكالسيوم والكلوريد أعلى في موسم الجاف بالمقارنة بالموسم الرطب. حوالي 80% من الآبار كان تركز كل من الصوديوم والبوتاسيوم أعلى في موسم الرطب بالمقارنة بالجاف. حوالي 80% من الآبار كان تركز النترات أعلى في موسم الرطب مقارنة بالموسم الجاف. تم تقييم نوعية مياه الري باستخدام العديد من معايير الري، جميع نماذج الآبار وقعت ضمن الاصناف 1S و 2S و 3S حسب مختبر الملوحة الأمريكي.

الكلمات المفتاحية: الجبس، الري، طبقة المياه الجوفية، نوعية المياه.

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