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Features of Well Water in Several Villages West of Mosul and Its Suitability for Aquaculture and Irrigation

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ABSTRACT

Due to the distance from sources of surface water, several villages have had to dig wells to meet their irrigation and drinking water needs. The goal of the current study was to assess groundwater quality for irrigation in a few villages west of Mosul. To achieve this, five wells were selected for analysis. Water samples were examined in a laboratory for the following variables: electrical conductivity (EC), the presence of positive and negative ions, residual sodium carbonate (RSC), percentage of sodium (%Na), sodium absorption rate (SAR), potential salinity (PS), permeability index (PI), and Kelly ratio (KR). The results indicated that some well samples had high salt concentrations, with the highest reaching 1802µS/ cm. However, other parameters such as %Na, SAR, KR, PI, and PS were within acceptable ranges for irrigation.

INTRODUCTION

Water is the source of life, a gift from God to all living things. The saying "There is no life without water" emphasizes the importance of water for sustaining life, making it a wise reminder of the need to preserve this vital resource. This blessing must be safeguarded, and appropriate management must be understood. Everyone, human or animal, can freely use it for civil, industrial, aquaculture and agricultural reasons **(Al-Hamdany, 2020)**. The world's growing social, agricultural, and industrial development presents numerous issues for water resources in general. In addition to the lack of water in many parts of the world, these sources are subject to pollution from trash that is thrown into them, being agricultural, industrial, or civil, in addition to the fact that many nations worldwide lack enough amount of water. According to statistics, water consumption increased by around six times in the last decade of the 20th century, which is more than twice the rate of population growth **(Al- Saffawi & Al Shuuchi, 2018; Sarfraz, 2018)**. This is anticipated to occur in 2025. Due to the growing demand for water brought on by global population growth, which raises water consumption and increases pollution of water resources, about one-third of the world's population will face a severe water crisis. As a result, significant efforts must be made to lessen pollution issues and carry out in-depth research on water resources while utilizing contemporary irrigation techniques to cut down on water usage **(Moghimi, 2016)**. Countless nations are at risk regarding water shortages, particularly those whose water supplies are located outside their boundaries, as is the case in Iraq. In order to accomplish their strategic objectives, countries with abundant water resources may attempt to control the springs of those water supplies and profit politically and economically from them. In addition to the previously mentioned, threats from decreasing precipitation because of climate change **(Al-Saffawi, 2018)** are to be considered.

The Tigris and Euphrates rivers in addition to several of their Iraqi tributaries have declined in level, resulting in an unavoidable water crisis for Iraq today. Thus, in order to handle this situation, scientific and workable solutions must be implemented. Some of these include utilizing the integrated water management principles, beginning to store and construct dams on rivers that never stop flowing, and making use of the groundwater that is now available. Additionally, it is important to successfully construct valley dams to capture seasonal flow. Alongside this, replacing outdated irrigation techniques with modern methods can help manage water scarcity **(Al-Qablan, 2018; Saeed *et al.*, 2018)**. Lastly, ongoing research on water resources is essential to identify urgent situations regarding pollution management **(Al-Hamdani *et al.*, 2021)**. In general, a number of criteria determine the quality of water appropriate for irrigation, such as:

1. Damage that may be caused by salinity, which is represented by electrical conductivity (EC) and latent salinity **(Al-Saffawi *et al*., 2018)**
2. Possible damage to permeability and filtration, as shown by residual sodium carbonate (RSC) and the permeability index (PI).Salinity of the soil and the sodium absorption rate (SAR) **(APHA , 1998)**.
3. Ion-induced toxicity, which can hinder the growth and productivity of various saltwater plants, such as sodium and chloride ions. The plant's kind and rate of absorption are the determining factors. Permeability and salinity are frequently related to this issue **(APHA, 2017)**.
4. Multiple impacts: in addition to bicarbonate and carbonate ions that influence pH, other effects of pH include the impact on carbonate balance and the capacity of plant roots to absorb minerals. High quantities cause calcium and magnesium ions to precipitate, leaving sodium ions in the soil solution. This in turn has an impact on the plants that grow in the soil as well as its formation and structure **(Al-Saffawi *et al*., 2020a)**. Therefore, the goal of the current study was to assess the well water quality of a few villages west of Mosul And its suitability for irrigation depending on salinity and sodality characteristics.

MATERIALS AND METHODS

1. Description of the study area

Five wells located in villages near the Tal Afar district, approximately 50km west of Mosul, were selected for the study: Tashta Village, Al-Ashiq Village, First Mazraa, Second Mazraa, and Abu Maria Village. These villages are located distant from sources of surface water, including rivers, as shown in Fig. (1). They are located approximately between latitudes 36º25'32"-36º27'36" North and longitudes 42º35'51"-42º41'05" East, as shown in Table (1). These wells are classified as deep type since they are deeper than 20 meters **(Al-Hamdany, 2020)**, and all these wells were of the closed type.

2. Geology of study area

In the study area, the Fatha formation (formerly known as the Lower Fares) is present and contains evaporite salts, dolomite, and gypsum, which contribute to low water quality. Consequently, many of the wells in this region exhibit water that has an unpalatable and bitter taste due to elevated concentrations of sulfate ions and total hardness **(Ibrahim *et al.*, 2000)**.

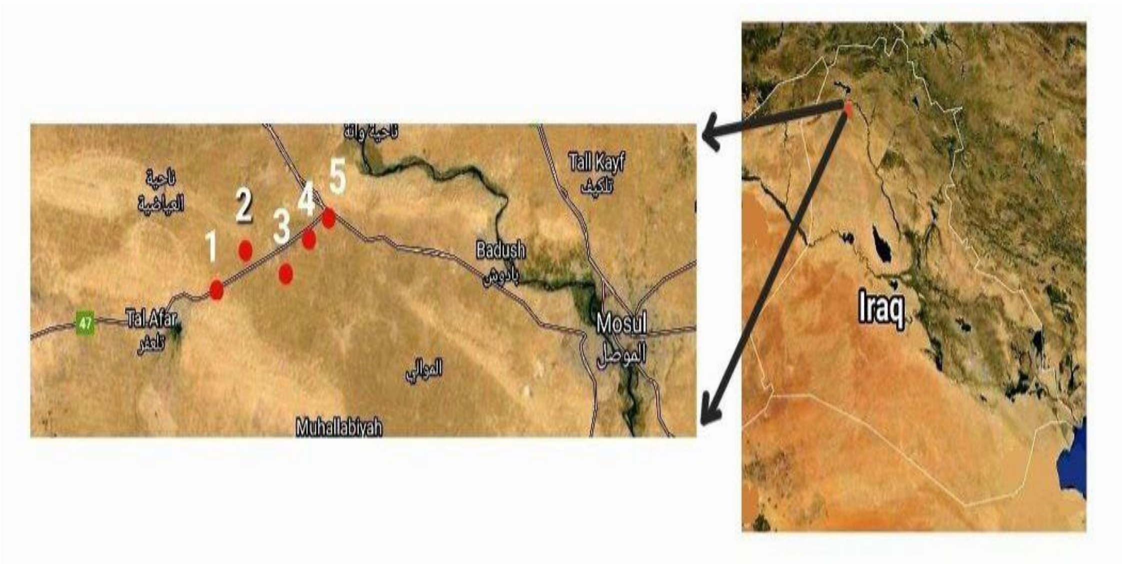

Fig. 1. Satellite images displaying the sites where water samples are collected

Table 1. Some specifications of the wells studied

Sample	Village	Sites		Depth
		N	E	
1	Abu Maria	36º25'32"	42º35'51"	44m
2	First Mazraa	36º26'30"	42º37'49"	48m
3	Second Mazraa	36º26'21"	42º38'16"	41m
4	Al-Ashiq	36º26'47"	42º39'50"	43m
5	Tashtah	36º27'36"	42º41'05"	51m

3. Methodology

Fifty water samples were collected from five different wells for a period of five months. Starting in November 2021 and lasting until March 2022, two sample each month was taken from each well, using sterile polyethylene bottles previously cleaned with distilled water.

4. Calculating important irrigation parameters

Based on worldwide standard procedures, the values of electrical conductivity (EC) and positive and negative ions were calculated **(APHA, 1998; APHA, 2017)**. The electrical conductivity values were measured using an EC- Meter model Mc-1, Mark V device, regulating the device with distilled water and adjusting the temperature to 25 degrees Celsius.

The residual sodium carbonate ratio (RSC), sodium percentage (Na%), sodium absorption ratio (SAR), potential salinity (PS), permeability index (PI) and Kelly ratio (KR) were also calculated, as shown in the following equations **(Richards, 1954)**:

$$RSC = (CO_3 + HCO_3) - (Ca + Mg)$$

$$Na\% = \frac{Na \times 100}{Ca+Mg+Na+K}$$

$$SAR = \frac{Na}{\frac{\sqrt{Ca+Mg}}{2}}$$

$$PS = \frac{1}{2} SO_4 + Cl$$

$$PI = \frac{Na+\sqrt{HCO3}}{Ca+Mg+Na} * 100$$

$$KR = \frac{Na}{Ca+Mg}$$

All values were expressed in milliequivalents per liter (meq. l^{-1}).

As for the ions of sodium, calcium, and magnesium, they were estimated using standard methods.

RESULTES AND DISCUSSION

1. Electrical conductivity (EC)

Electrical conductivity plays a crucial role in assessing the suitability of water for irrigation. It is a numerical representation of the total dissolved salts in water **(Qabalan, 2018)**. This metric reflects the water's ability to conduct electrical current, influenced by both water temperature and the quantity and quality of dissolved ions **(APHA, 1998)**. According to the findings presented in Table (2), the study reveals elevated electrical conductivity values in the wells under investigation. This increase may be attributed to the geological formations in the research well area, particularly the Fatha formation with its components of dolomite, gypsum, and evaporate salts, as well as the Injana formation. These geological features are reflected in the water quality and likely contribute to the observed higher conductivity levels **(Al-Saffawi, 2018; Al-Saffawi *et al.*, 2020b)**. Based on electrical conductivity (EC) values from the American Salinity Laboratory, and comparing the study results in Table (2), it was observed that all the wells under the study were assigned to Class C_3, indicating high salinity which is appropriate for plants tolerant of salinity as well as soils requiring frequent drainage operations **(Al-Yozbeki & Suleiman, 2020)**.

Table 2. Results of electrical conductivity values and some irrigation standards for the well water studied

Location		EC[1]	RSC[2]	Na%	SAR	PS	PI	KR
1	Min	996.48	-14.00	3.62	0.880	5.10	6.38	0.094
	Max	1193.0	-49.00	39.0	0.710	7.20	7.90	0.047
	Mean	1096.0	-31.74	18.8	0.800	6.15	7.14	0.064
2	Min	1180.8	-26.90	3.46	0.875	2.96	10.3	0.075
	Max	1303.7	-52.60	37.3	0.736	6.10	87.1	0.047
	Mean	1236.0	-37.56	23.5	0.790	4.53	47.5	0.059
3	Min	1200.0	-24.89	3.66	1.176	3.88	9.92	0.110
	Max	1351.7	-35.80	39.4	1.098	8.40	87.4	0.085
	Mean	1268.0	-30.56	24.1	0.994	6.14	38.9	0.082
4	Min	680.32	-9.100	3.32	2.000	2.59	9.61	0.250
	Max	1802.2	-51.90	35.8	2.852	4.71	82.8	0.150
	Mean	1343.0	-33.56	15.9	2.270	3.65	49.77	0.160
5	Min	1396.5	-21.00	3.52	1.675	6.38	9.58	0.160
	Max	1546.9	-42.70	38.6	1.957	7.90	82.5	0.140
	Mean	1458.0	-30.16	14.7	1.869	7.14	45.9	0.150

[1] µS. Cm^{-1}., [2] meq. L^{-1}

2. Residual sodium carbonate (RSC)

The **residual sodium carbonate** is regarded as a significant indicator for irrigation. Carbonate and bicarbonate ions have the tendency to precipitate both calcium and magnesium in the soil solution in the form of calcium and magnesium carbonate **(Al-Saffawi & Al-Shanoona, 2013)**, which lowers the concentration of these ions in the soil solution. This result regarding the dominance of sodium ions are bad for plants and have an adverse influence on the structure and development of soil. If these ions are present in irrigation water, a negative effect will be spotted on the amount and quality of produce **(Al-Maadidi, 2017)**.

Based on Table (2), the negative sodium carbonate readings suggest that all of the study wells' water samples are appropriate for irrigation according to the approved classifications **(Das & Nag, 2014)**. This can be explained by the fact that these wells have higher concentrations of calcium and magnesium carbonate compared to bicarbonate ions. This may result from well water flowing over or through layers saturated with calcium and magnesium salts, lowering the residual sodium carbonate values **(Al-Aqidi, 2007)**.

3. Na hazard and sodicity (Na% and SAR)

According to **Al-Hayali (2010)**, the element sodium is the sixth most common element in natural water, and its high concentration in irrigation water negatively affects the soil's permeability and structure. Consequently, this will hinder soil washing and will lessen the amount of extra irrigation water that filters down to the lowest levels of all salts, which will consequently have a detrimental effect on the process and caliber of plant production **(Simsek & Gunduz, 2007)**. The sodium absorption rate (SAR) and the percentage of sodium (Na%) are two indicators that can be used to indicate sodium in irrigation. The water quality of the wells under study is found to be good for irrigation with respect to both Na% and SAR values when compared to the international irrigation classifications, which indicate that the water cannot dissolve calcium carbonate. However, when the irrigation water meets soil, some calcium and magnesium will precipitate out of it **(Al-Nasser & Abbas, 2012)**.

4. Potential salinity (PS)

The potential salinity expresses the combined effects of ions that are both sulfate and chloride, particularly when irrigation is involved. Since they contribute to the processes that increase soil salinity and the effects of irrigation on plants, their impacts on the plant also cause a decline in productivity in addition to those consequences in plain sight on leaves of plants **(Qabalan, 2018)**.

The results of the current study were compared to the Doneen classification **(Doneen, 1954)**, revealing the following ratings for the water samples: Wells 1 and 3 are good for irrigating high-permeability soils and average for medium-permeable soils, while Well 5 is average for high-permeability soils but poor for medium-permeable soils.

Table 3. Doneen's classification of irrigation water quality according to the concentration of latent salinity (**Doneen, 1954)**

Soil quality / Water quality	P. Salinity meq.L^{-1}		
	High permeability soil	**Medium permeability**	**Poor permeability**
Good	Less than 7.0	Less than 5.0	Less than 3.0
Medium	7- 15	5- 7	3- 5
lousy	Older than 15	Older than 7	Greater than 5

5. Permeability index PI

The appropriate amount of water for irrigation is determined by the concentrations of various ions, including calcium, magnesium, sodium, and bicarbonate, as well as the processes occurring in the soil solution, such as cation exchange. High concentrations of bicarbonate and sodium ions can impact this balance. Prolonged soil use can deteriorate permeability, adversely affecting seed growth and development **(Nag & Das, 2014)**. However, the study found that all water samples from the investigated wells were of an appropriate quality for irrigation based on recognized international classifications.

6. Kelly's ratio KR

One of the essential and crucial factors for evaluating the quality of irrigation water is the Kelly index or ratio (KR), which is a measurement of the ratio of the concentration of sodium ions to the concentrations of both calcium and magnesium ions **(Gungor & Arslan, 2016)**. In addition, it reveals the degree to which this water affects the properties and traits of the soil as well as the growth and productivity of plants. According to the accepted international classifications for irrigation water, all analyzed well water is suitable for irrigation. This is supported by the results in Table (2), which indicate relatively low values of the Kelly ratio (KR) for all studied well water samples.

7. Positive ions (Calcium, magnesium and sodium)

Calcium and magnesium are among the most important positive ions present in well water, as they are among the most important causes of hardness in water **(Al-Saffawi *et al.*, 2020)**. It is clear from Table (4) that the values of dissolved calcium and magnesium ions have varied, as their concentrations depend on the type of rocks through which they passed, which may most likely be limestone and dolomite. This is similar to what was found by **Al-Nasser and Abbas (2012)** in his study of the water of wells and springs in the Zamar region.

As for sodium, it is considered important in classifying irrigation water. High concentrations of it cause soil permeability problems, in addition to its toxic effect on plants irrigated with it, as burns appear on the edges of the leaves **(Al-Saffawi *et al*., 2020)**. It is shown in Table (4) that sodium ion concentrations in all the water of the study wells are generally low, and that using them for irrigation purposes does not cause toxic risks to the plants irrigated with them.

Table 4. Results of positive ion concentrations for well water in units (mEq/L)

Location		**Ca^{+2}**	**Mg^{+2}**	**Na^{+}**
1	Min	16.0	56.0	2.04
	Max	26.8	30.4	2.69
	Mean	22.8	15.3	2.46
2	Min	25.2	8.00	2.52
	Max	32.0	28.8	2.87
	Mean	28.7	16.0	2.64
3	Min	24.0	6.00	3.22
	Max	28.4	13.6	3.56
	Mean	25.6	11.1	3.01
4	Min	9.60	6.00	3.95
	Max	26.0	34.4	8.82
	Mean	20.0	20.7	6.78
5	Min	24.0	4.00	4.43
	Max	27.2	20.8	9.78
	Mean	25.3	11.3	5.66

CONCLUSION AND RECOMMENDATION

The study concludes that the water from the analyzed wells is suitable for irrigating certain salt-tolerant crops and soils that require regular drainage. Specifically, 40% of the well water is suitable for irrigating high-permeability soils, while another 40% is appropriate for medium-permeability soils. Additionally, it is average for irrigating poor-permeability soils. Conversely, 20% of the samples were deemed poor for irrigating low-permeability soils but moderate for medium-permeability soils. The water from the studied wells was found to fall within acceptable ranges for sodium content, indicating that plant growth is not adversely affected.

The study also recommends increasing the number of wells in these areas and conducting further research on their suitability for both agricultural and civil applications. It is essential to avoid using saline water for irrigation since this can lead to soil salinization and a gradual loss of agricultural viability. Physical methods, such as freezing, should be employed to reduce salt concentrations in well water. Additionally, testing for heavy metals, radioactive materials, and pesticides in well water intended for drinking and irrigation is advised.

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