International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 1 (2018) pp. 697-706

Chemical Indices of Water Quality in the Zarqa River-Jordan: Concentrations of Major Cations and Water Suitability for Irrigation.

Alsharifa Hind Mohammad[*1a], Mahmoud Mohammad Abualhaija[*1b] and Maisa'a Wasif Shammout[*1c]

[1] Water, Energy and Environment Center, The University of Jordan, 11942, Jordan.

ORCIDs: [a]0000-0002-4423-1092, [b]0000-0002-4341-5308, [c]0000-0002-1026-5999,

Abstract

Jordan is one of the world's driest countries; it has very limited resources as the demand for water exceeds available water resources, recently the problem of water scarcity increased dramatically due to increasing needs as a consequence of the increase in population and refugees. This study was conducted on the Zarqa River in Jordan; it is one of the largest rivers in Jordan. The water quality of Zarqa River was evaluated from different water quality parameters such as calcium (Ca^{2+}), sodium (Na^{+}), magnesium (Mg^{2+}), potassium (K^{+}), electrical conductivity (EC), sodium adsorption ratio (SAR), sodium percentage (Na%) and magnesium hazard (MH) and Kelly's ratio (KR). EC data showed that only 7% of water samples are good for irrigation, whereas 93% are in the doubtful category. Mg Hazard data revealed that all water samples are suitable for irrigation. KR data for all samples showed that just 45% of the collected samples are suitable for irrigation uses, whereas 55% are in the marginal category. The analysis of Wilcox Diagram indicated that the majority of water samples falls under the categories of high salinity and low to medium alkalinity (sodium hazard), which proves the seriousness of the water quality. High salinity in Zarqa River water requires serious attention and awareness, crops salt tolerance should be selected even with good drainage soils, and thus special sodium and salinity control are required to reduce the sodium and salinity hazard. Evaluation on a regular basis will assist planners, agriculturalists, scientists in selecting suitable alternatives and adjusting management's strategy to cope with potential water quality-related problems. Further studies will be conducted on water quality along the Zarqa River that might be helpful under prevailing conditions of use.

Keywords: Zarqa River, Irrigation, Sodium Adsorption Ratio, Sodium Percentage, Magnesium Hazard, Kelly's Ratio, Wilcox Diagram.

INTRODUCTION

Jordan has faced the problem of water scarcity for many decades and improved the efficiency of water usage is an important component of its endeavor to deal with the problem. Physical, chemical and bacterial characteristics of surface water can be used to determine its suitability for domestic, industrial, municipal and agricultural applications (Mohammad et al., 2015). Suitability of water for irrigation depends on several factors, including the quality of water, soil type, characteristics of salt tolerance of the plants, soil climate and drainage characteristics.

The changes of chemical properties in surface and groundwater depend on several elements such as water source, evaporation rate, the interaction of water with reactive minerals and types of rock and minerals in the water environment (Deshpande and Aher, 2012). Therefore, sufficient information on surface and groundwater chemistry is needed to give a better evaluation of the water quality.

Zarqa River area is a semi-arid area with an average rainfall about 300 millimeters per year, which is not sufficient for domestic and agriculture purposes. Therefore, treated wastewater produced from wastewater treatment plants (WWTP) flow out along the Zarqa River and merges with the water in the river and eventually used for irrigation purposes (Shatanawi and Shammout, 2011; Shatanawi et al., 2008).

Groundwater in Zarqa River Basin represents the main source of water supply in the basin. The outcrop areas include the highest concentration of wells, where depletion and deterioration in water quality have reached critical stages (Mohammad et al., 2016), groundwater overpumping from Zarqa basin has seriously affected the base flow of the river. Many springs along the Zarqa River have dried up completely reducing the base flow from 3- 4 m^3/s to less than 1 m^3/s. This situation has created a serious environmental problem in affecting the fauna and the flora of the river. No short term or long term measures have been taken to consider the allocation for the environment. These cases are considered conflict cases between the situation and the environment (Shammout et al., 2013; Shatanawi and Shammout, 2011).

STUDY AREA

Zarqa River is one of the largest rivers in Jordan after Jordan River and Yarmouk River, therefore Zarqa River basin is one of the most vital basins in Jordan with respect to its economic, social and agricultural importance. The basin is located between 213° to 319° east and 140° to 220° north and covers an area of 3567 square kilometers (Figure 1).

More than 65% of the population and about 78% of the industries in Jordan reside along the Zarqa River basin area this makes the river the focus of attention of government, academic and research institutions. There are two principal branches of the Zarqa River the first one is Wadi Dhulail and the second one is Seil Al-Zarqa. The discharges in Wadi Dhulail come from the eastern area while discharges in Seil

Al- Zarqa come from the western area. The two branches converge at Al-Sukhna area to form the Zarqa River. The main sources of water in Zarqa River are from annual precipitation, small springs, and effluents from wastewater treatment plants (such as Al-Samra, Jerash, Abu Nssair and Baqa'a WWTPs), and from industrial plants between Amman and Zarqa area. The effluents from industrial and wastewater treatment plants contribute about 50% of the water reaching the King Talal Dam (KTD) through the Zarqa River with an average annual inflow around 113 MCM. KTD regulates the Zarqa River before its water is released for irrigation purposes in the Jordan Valley (Abu-Hilal and Abualhaija, 2010; Bandel and Salameh, 1979; Bandel and Salameh, 1981; Ministry of Environment, 2006; RSS, 1984-2004).

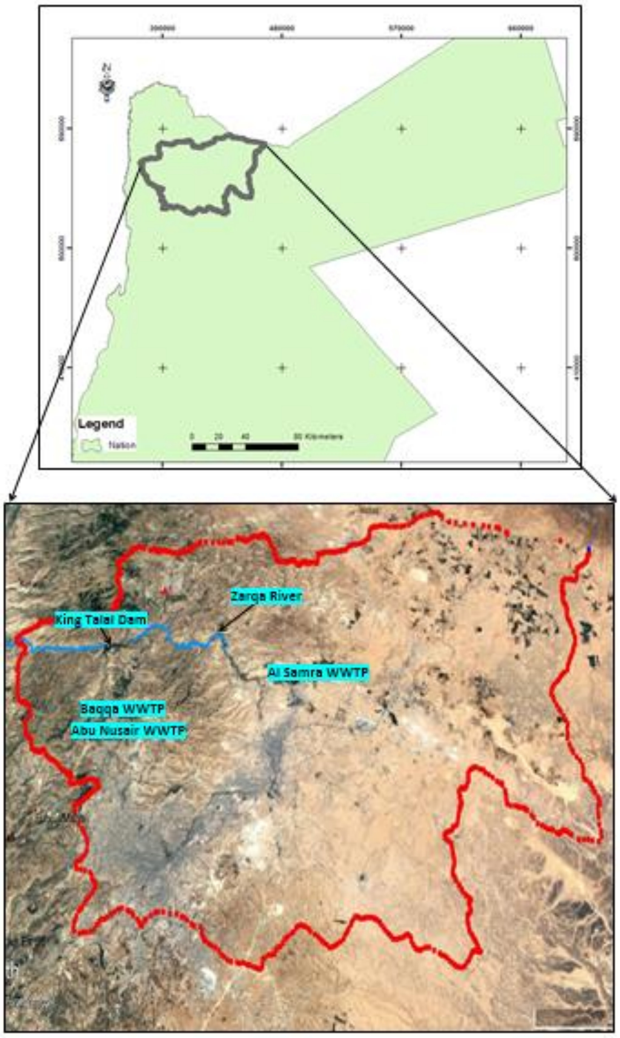

Figure 1: location map of the study area showing the Zarqa River, King Talal Dam (KTD) and different WWTPs.

MATERIAL AND METHODS

The present work was conducted to determine the chemical indices of surface water contamination in Zarqa River based on the concentrations of major cations (Ca, Na, Mg and K) and EC values; forty-two samples were randomly collected from the surface water along the Zarqa River between May to August 2015. All samples and sample containers were cleaned and pre-prepared in the lab, after that and before the samples collection all samples were rinsed 3 times with the targeted water. Finally, after samples collection, all samples were sealed and returned to the laboratory for analysis.

Analyses were conducted at the Laboratory of Water, Energy, and Environment Centre (WEEC) at the University of Jordan according to the Standard Methods of the American Public Health Association (Rice et al., 2012).

Many parameters that reflect the irrigation water quality, including Ca, Mg, Na, and K and EC were measured in this study. These parameters and methods are shown in Table 1.

The evaluation of water quality in the Zarqa River is based on the chemical indices: electrical conductivity (EC), sodium adsorption ratio (SAR), sodium percentage (Na %) and magnesium hazard (MH) and Kelly’s ratio (KR).

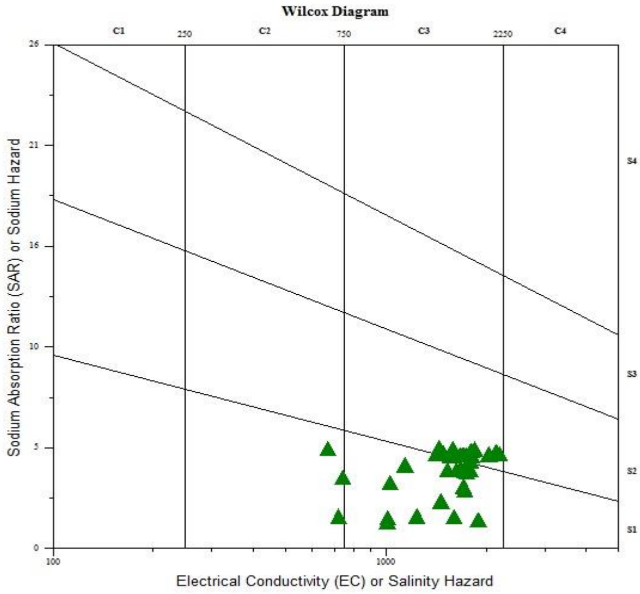

Figure 2: Wilcox Diagram of the surface water samples collected from the Zarqa River.

RESULTS AND DISCUSSIONS

Electrical Conductivity (EC):

Electrical conductivity is an indication of the concentration of total dissolved solids and major ions in a given water source which is simply defined as an indicator of the total salinity or salinity hazard. The samples collected from the Zarqa River in the present study showed a variation ranged between 670 and 2189 micromhos/cm with an average of 1575 micromhos/cm. Based on the classifications for EC in (Table 2); three samples of forty-two collected samples are found less than 750 micromhos/cm which indicates that 7% of the samples are good for irrigation uses. Thirty-nine samples of the forty-two collected samples are found between 750 and 2250 micromhos/cm indicates that 93% of the water samples are in the doubtful range. High EC values in irrigation water affect the crop productivity and can lead to saline soil condition, where the high EC values prevent the plant from competing with ions in the soil solution, thus less water is available in the root zone of the plant due to osmotic pressure.

The EC values of the majority of the samples in the present study are in the doubtful category (Table 1) that means salinity may adversely affect plants and the water cannot be used on soils with restricted drainage, crops with good salt tolerance should be selected even with good drainage soils.

Sodium Absorption Ratio (SAR):

Sodium (or alkali) hazard in irrigation water is determined by the absolute and the relative concentration of cations and expressed in terms of SAR or the sodium absorption ratio. In that respect, there is a significant relationship between the SAR values in irrigation water and the sodium absorption rate by the soil, wherein the higher sodium and lower calcium and magnesium values in irrigation water indicate that the cation - exchange complex may become saturated with sodium, but if there are large enough quantities of magnesium and calcium in the soil this will counter the effects of the sodium and help to maintain good soil properties. SAR value is an indication of the availability of soil pore water to plant roots, high SAR values and excess sodium concentrations in irrigation water affect the soil properties and reducing its permeability and infiltration rate (Allison et al., 1968; Weiner, 2012).

$$SAR = \frac{Na}{\sqrt{(Ca+Mg)/2}}$$ (*ions units meq/liter*) (Karanth, 1987)

The SAR value for a given water sample provides a valuable index of the sodium hazard for soils and crops, the lower ionic strength of the solution gives the greater sodium hazards at a given SAR value (Bouwer, 1978).

In the present work, SAR values showed variation from 1.38 and 5.2 (Table 5) with an average value of 4.1, SAR classifications in (Table 3) indicate that all the samples collected from the Zarqa River were less than 10, which indicates that all the collected samples belong to the excellent category for irrigation. Consequently, the water in the Zarqa River can be used for irrigation with little risk of harmful levels of sodium. Nevertheless, crops that are sensitive to sodium can accumulate harmful concentrations of sodium (Burger and Celkova, 2003).

The concentrations of Major Cations

Calcium is the fifth most abundant element in the earth's crust, it is an important element for plant growth, the main sources of calcium in natural water come from streams flowing over limestone, $CaCO_3$, gypsum and other calcium-containing rocks and minerals (Nikanorov and Brazhnikova, 2009). The concentration of Ca^{2+} in the study area varies from 57 to 140 mg/l as shown in Table 4 and Figure 3, with an average concentration of 100 mg/l. The comparison of these results with the Jordanian permissible limit for the use of reclaimed water for irrigation purposes (2006) (Table 6) showed that they are below 230 mg/l which is the maximum level allowed.

Sodium (Na^+) is the sixth most abundant element in the earth's crust after calcium, nearly all sodium compounds are readily dissolved in water, and it naturally leaches from rocks and soils, sodium is an important element in determining the suitability of water for irrigation (Priyadarshi, 2005). The concentrations of Na^+ in Zarqa River water range from 59 mg/l and 269 mg/l (Table 4 and Figure 3) with an average concentration of 185 mg/l. Correlating these results with the Jordanian allowable limit for the use of reclaimed water for irrigation purposes (2006) (table 6), the majority of samples (81%) are below 230 mg/l which is the maximum level allowed whereas 19% of the samples are above the Jordanian permissible limit (Table 6).

Magnesium (Mg^{2+}) is one of the most abundant elements in the earth's crust, Mg^{2+} is never found free in nature. It is classified as a secondary nutrient, but it has a major effect on crop and animal production (Kirkby and Mengel, 1976). The concentration of Mg^{2+} in the present study is in the range of 23 mg/l – 57 mg/l (Table 4 and Figure 3) with an average concentration of 34 mg/l. Correlating these results with the Jordanian permissible limit for the use of reclaimed water for irrigation purposes (2006) (Table 6), they are below 100 mg/l which is the maximum level allowed.

Potassium (K^+) is also one of the most abundant elements in the earth's crust, it is an important element since it is one of the essential nutrients for the plant and animals, it is also naturally leached from rocks and soils (Hem, 1985). The concentration of K^+ in this work ranges between 4 mg/l and 33 mg/l (Table 4 and Figure 3) with an average concentration of 22 mg/l.

Sodium percentage (Na%)

The determination of sodium concentration in irrigation water is necessary due to its hazard on soils. High and excess sodium concentration in irrigation water affects and changes the soil properties such as clogging of soil particles as a result of reacting sodium with soil. Sodium adsorption by clay particles in the soil leads to displacing Mg^{2+} and Ca^{2+} ions, thus reduce the soil permeability and cause poor internal drainage (Rao, 2006; Todd, 1980).

The sodium percentage can be calculated by the following formula:

$$Na\% = (Na^+ \times 100) / (Na^+ + Ca^{2+} + Mg^{2+})$$ (Raghunath, 1987; Wilcox, 1955)

Where, the units of Na^+, Ca^{2+} and Mg^{2+} are in milliequivalents per liter (meq/liter)

The results of Na% in the study area are given in Table 5, and they show variations from 26.21 to 58.08. The classifications of water for irrigation based on Na% in Table 2 showed that 1% of the collected samples had good water irrigation quality, while 83% had permissible irrigation water quality.

Magnesium hazard (MH) or Magnesium Ratio (MR)

Magnesium hazard is calculated by the following equation (Raghunath, 1987):

$$\text{Magnesium hazard (MH)} = (Mg^{2+} \times 100) / (Ca^{2+} + Mg^{2+})$$ (*ions units meq/liter*)

The excess concentration of magnesium in the soil causes infiltration problems and can lead to reduced crop yield (Ayer and Westcot, 1985). MH > 50 is considered harmful and unsuitable for irrigation purpose (Gupta and Gupta, 1987) (Table 3), the values of magnesium hazard in the present study ranged between 27.22 and 45.78 (Table 5) this indicating that ensures no such effect to soil, thus all the water samples collected from Zarqa River are suitable for irrigation uses.

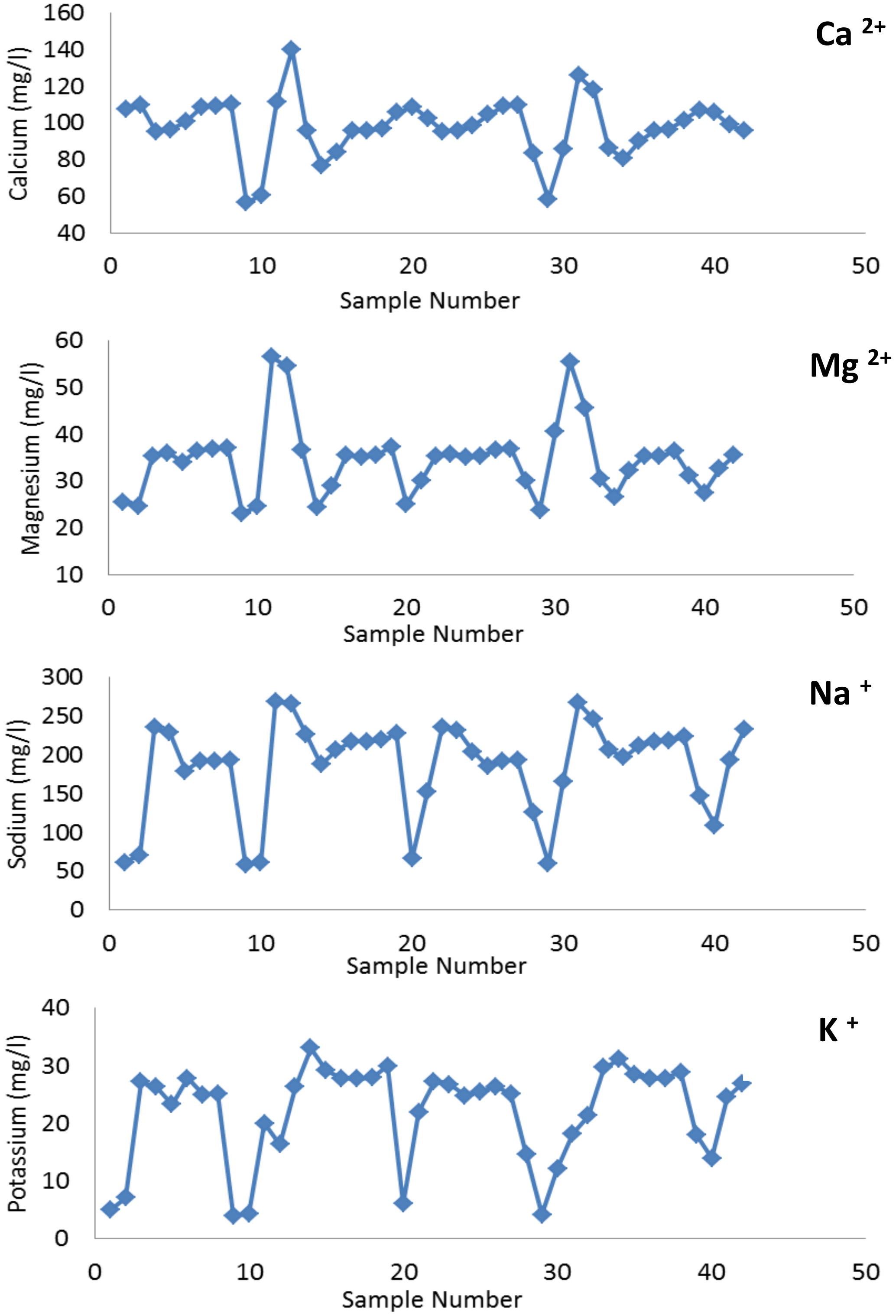

Figure 3: Distribution of calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), and potassium (K^{+})) in the collected water samples from the Zarqa River

Kelley's Ratio (KR):

Kelley's ratio can be used to determine the suitability of water for irrigation. The measurement of the concentration of Na^+ against Ca^{2+} and Mg^{2+} is known as Kelley's ratio (Kelley, 1963).

Kelly's Ratio (KR) = $Na^+ / Ca^{2+} + Mg^{2+}$ (*ion units meq/liter*)

In irrigation water, if the value of KR is more than 2 which means an extra value of sodium exists in the water and the water is not suitable for irrigation. If the KR value in the range 1-2 that means the water is under the category of marginal (Table 3), whereas if the KR value is less than 1 which means that the water is suitable for irrigation (Kelley, 1946).

The results of the present study show that the KR values vary between 0.36 and 1.39 as shown in Table 6, nineteen samples of the forty-two samples have KR values of less than 1, which indicates that 45% of the samples collected from the Zarqa River are suitable for irrigation, whereas 55% of the samples are in the range 1-2 and fell under the category of marginal for irrigation (Table 3). Accordingly and based on KR classifications, all samples collected from the Zarqa River are suitable and marginal for irrigation.

Wilcox Diagram

Wilcox Diagram can be used to determine the suitability of water for irrigation (Wilcox, 1955). Figure (2) represents the Wilcox diagram; a plot of the sodium absorption ratio (SAR) on the Y-Axis against electrical conductivity (EC) on the X-axis.

According to Wilcox diagram, water can be classified into four types based on EC and four types based on SAR, the classifications based on EC (or salinity hazard) are: C1 (low salinity hazard), C2 (medium salinity hazard), C3 (high salinity hazard), and C4 (very high salinity hazard), whereas the second classifications based on SAR (or sodium hazard) are: S1 (low sodium hazard), S2 (medium sodium hazard), S3 (high sodium hazard), and S4 (very high sodium hazard).

On the basis of Wilcox diagram data (Figure 2), 7% of the water samples collected from the Zarqa River belong to S1C2, low sodium hazard and a medium salinity hazard category that could be used for irrigation with little risk of dangerous levels of exchangeable sodium and if a moderate amount of leaching occurs. 50% of the samples belong to S1C3, low sodium hazard and high salinity hazard category that cannot be used for irrigation on soils with restricted drainage as well as the little risk of dangerous levels of exchangeable sodium. The rest 43% of the samples belong to S2C3, medium sodium hazard and high salinity hazard category and cannot be used for irrigation on soils with restricted drainage. Most of the samples collected from the Zarqa River belong to (S1, S2-C3) categories, low and medium sodium hazard and high salinity hazard. Special sodium and salinity control are required to reduce the sodium and salinity hazard. Water belonging (S1, S2-C3) categories can be used on coarse-textured soils with good permeability, but with the risk of alkalinity problems in fine-textured soils with restricted leaching conditions, even with an adequate drainage system, special procedures might be needed to control salinity.

CONCLUSIONS AND RECOMMENDATIONS

- The quality of surface water of the Zarqa River has received research interest on the need to evaluate its suitability for irrigation. The majority of the water samples are affected by high values of salinity.
- The concentrations of major cations (calcium, magnesium, and potassium) in all surface water samples of the Zarqa River are less than the standard Jordanian permissible limits for irrigation purposes. While 19 % of the water samples have sodium concentrations that exceed the allowable Jordanian limits for irrigation purposes.
- Employment of chemical Indices in the present study has been found helpful in assessing the quality of water in Zarqa River. Sodium Absorption Ratio (SAR), Sodium percentage (Na%), Magnesium hazard (MH) and Kelley's Ratio (KR) of Zarqa River water were calculated from different physicochemical parameters in order to assess the suitability of Zarqa River water for irrigation purposes. On the basis of SAR and MH data, all surface Zarqa River water samples are good for irrigation purposes. Whereas on the basis of N % and KR data, all the water samples are good to permissible for irrigation purposes.
- According to Wilcox Diagram, 7% of surface water samples of the Zarqa River belong to S1-C2, of low sodium hazard and medium salinity hazard category that could be used for irrigation if a moderate amount of leaching occurs. Most of surface water samples of the Zarqa River (93%) belong to (S1, S2- C3), of low and medium sodium hazard and high salinity hazard categories that cannot be used on soils with restricted drainage although they have danger for the development of harmful levels of exchangeable sodium. Special sodium control and soil management are required to reduce the salinity and sodium hazard before irrigation.
- It can be concluded from the present study that the quality treatment for surface water of the Zarqa River needed specific control and procedures to reduce salinity and sodium hazards before its use for irrigation.
- Specific irrigation uses of Zarqa River water should be selected (e.g. crops with good salt tolerance).
- Control procedures of the water quality are required by using suitable alternatives and adjusting management's strategy to cope with potential water quality-related problems.

ACKNOWLEDGMENT:

This paper is one of the results of the project: Studying the effects of using the effluent of King Talal dam water in irrigation on soils and groundwater in evaluating of groundwater vulnerability maps for the area, funded by Scientific Research Support Fund/ Amman, Jordan.

Table 1: Parameters and Methods of Analysis (American Public Health Association, 2012) (Rice et al., 2012).

Symbol	Water Parameter	Method of Analysis
Ca	Calcium	3500-Ca B EDTA Titritmetric method
Mg	Magnesium	2340-C-EDTA Titrimetric method
Na	Sodium	Na Sodium 3500-Na B Flame emission photometric method
K	Potassium	3500-K B Flame Photometry Method
EC	Electrical Conductivity	Field conductivity meter EC-4500-H B electrometric method

Table 2: Classifications of water for irrigation based on EC values (Handa, 1969; Wilcox, 1955).

Classes of Water	Quality of water	Limiting values of EC (μs/cm)	Total No. of samples (Out of total 20 samples)	Percentages %
C1	Excellent	< 250	0	0 %
C2	Good	250 – 750	3	7 %
C3	Doubtful	750 – 2250	39	93 %
C4	Unsuitable	> 2250	0	0 %

Table 3: Classification of water for irrigation based on SAR (Richards, 1954), KR (Kelley, 1946), Mg Hazard (Gupta and Gupta, 1987) and Na percentage (Raghunath, 1987).

Classification scheme	Category	Ranges	Number of samples	Percentage of samples (%)
SAR	Excellent (Low sodium hazard)	0 - 10	42	100
	Good (Medium sodium hazard)	10 - 18	0	Nil
	Fair (High sodium hazard)	18 - 26	0	Nil
	Poor (Very high sodium hazard)	> 26	0	Nil
Mg Hazard	Suitable	< 50	42	100
	Unsuitable	> 50	0	Nil
Kelly's ratio	Suitable	< 1	19	45
	Marginal	1-2	23	55
	Unsuitable	>2	0	Nil
Na %	Excellent	< 20	0	Nil
	Good	20 - 40	7	17
	Permissible	40 - 60	35	83
	Doubtful	60 - 80	0	Nil
	Unsuitable	> 80	0	Nil

Table 4: Concentrations of Major Cations (in mg/l and meq/liter) in the samples collected from the Zarqa River.

Sample ID	Sodium (Na^+)		Potassium (K)		Magnesium (Mg^{2+})		Calcium (Ca^{2+})	
	(mg/l)	(meq/l)	(mg/l)	(meq/l)	(mg/l)	(meq/l)	(mg/l)	(meq/l)
1.0	61.4	2.67	5.0	0.13	25.5	2.13	107.7	5.39
2.0	70.4	3.06	7.1	0.18	24.6	2.05	109.8	5.49
3.0	235.0	10.22	27.1	0.68	35.3	2.94	95.4	4.77
4.0	228.7	9.94	26.3	0.66	36.0	3.00	96.4	4.82
5.0	179.3	7.80	23.2	0.58	34.1	2.84	100.7	5.04
6.0	192.0	8.35	27.8	0.70	36.5	3.04	108.5	5.42
7.0	192.3	8.36	25.0	0.62	36.8	3.07	109.5	5.47
8.0	192.9	8.39	25.2	0.63	37.1	3.09	110.2	5.51
9.0	58.7	2.55	4.0	0.10	23.1	1.92	56.6	2.83
10.0	61.3	2.67	4.3	0.11	24.5	2.04	60.6	3.03
11.0	268.9	11.69	20.0	0.50	56.5	4.70	111.4	5.57
12.0	265.5	11.54	16.4	0.41	54.5	4.54	140.2	7.01
13.0	226.3	9.84	26.3	0.66	36.7	3.06	95.8	4.79
14.0	187.3	8.14	33.0	0.83	24.3	2.03	77.1	3.85
15.0	206.2	8.96	29.1	0.73	29.0	2.42	84.2	4.21
16.0	217.3	9.45	27.8	0.69	35.6	2.97	95.8	4.79
17.0	217.3	9.45	27.7	0.69	35.1	2.92	95.6	4.78
18.0	219.6	9.55	27.9	0.70	35.5	2.96	97.2	4.86
19.0	227.5	9.89	29.9	0.75	37.3	3.11	105.7	5.28
20.0	65.9	2.86	6.0	0.15	25.1	2.09	108.8	5.44
21.0	152.7	6.64	21.9	0.55	30.0	2.50	102.6	5.13
22.0	235.0	10.22	27.1	0.68	35.3	2.94	95.4	4.77
23.0	231.8	10.08	26.7	0.67	35.7	2.97	95.9	4.80
24.0	204.0	8.87	24.8	0.62	35.1	2.92	98.6	4.93
25.0	185.7	8.07	25.5	0.64	35.3	2.94	104.6	5.23
26.0	192.2	8.36	26.4	0.66	36.7	3.06	109.0	5.45
27.0	192.6	8.38	25.1	0.63	37.0	3.08	109.8	5.49
28.0	125.8	5.47	14.6	0.36	30.1	2.51	83.4	4.17
29.0	60.0	2.61	4.1	0.10	23.8	1.98	58.6	2.93
30.0	165.1	7.18	12.1	0.30	40.5	3.37	86.0	4.30
31.0	267.2	11.62	18.2	0.45	55.5	4.62	125.8	6.29
32.0	245.9	10.69	21.4	0.53	45.6	3.80	118.0	5.90
33.0	206.8	8.99	29.7	0.74	30.5	2.54	86.4	4.32
34.0	196.8	8.55	31.1	0.78	26.6	2.22	80.6	4.03
35.0	211.7	9.21	28.4	0.71	32.3	2.69	90.0	4.50
36.0	217.3	9.45	27.7	0.69	35.3	2.95	95.7	4.79
37.0	218.4	9.50	27.8	0.69	35.3	2.94	96.4	4.82
38.0	223.5	9.72	28.9	0.72	36.4	3.03	101.4	5.07
39.0	146.7	6.38	18.0	0.45	31.2	2.60	107.2	5.36
40.0	109.3	4.75	14.0	0.35	27.5	2.29	105.7	5.28
41.0	193.9	8.43	24.5	0.61	32.6	2.72	99.0	4.95
42.0	233.4	10.15	26.9	0.67	35.5	2.96	95.7	4.78

Table 5: Values of sodium absorption ratio (SAR), Kelley's ratio (KR), sodium percentage (Na%) and magnesium hazard (MH) in the samples collected from the Zarqa River.

Sample ID	SAR	Mg Hazard (MH)	Kelly's ratio (KR)	Na %
1.0	1.38	28.29	0.36	26.21
2.0	1.58	27.22	0.41	28.87
3.0	5.20	38.14	1.32	56.99
4.0	5.03	38.38	1.27	55.96
5.0	3.93	36.06	0.99	49.75
6.0	4.06	35.94	0.99	49.65
7.0	4.05	35.92	0.98	49.46
8.0	4.04	35.94	0.98	49.37
9.0	1.66	40.45	0.54	34.94
10.0	1.67	40.27	0.53	34.45
11.0	5.16	45.78	1.14	53.22
12.0	4.80	39.32	1.00	49.99
13.0	4.97	38.97	1.25	55.62
14.0	4.75	34.45	1.39	58.08
15.0	4.93	36.46	1.35	57.51
16.0	4.80	38.25	1.22	54.91
17.0	4.81	37.94	1.23	55.08
18.0	4.83	37.82	1.22	54.99
19.0	4.83	37.07	1.18	54.09
20.0	1.48	27.76	0.38	27.57
21.0	3.40	32.74	0.87	46.54
22.0	5.20	38.14	1.32	56.99
23.0	5.11	38.26	1.30	56.48
24.0	4.48	37.22	1.13	53.05
25.0	3.99	36.00	0.99	49.70
26.0	4.05	35.93	0.98	49.56
27.0	4.05	35.93	0.98	49.42
28.0	2.99	37.55	0.82	45.03
29.0	1.66	40.36	0.53	34.69
30.0	3.66	43.96	0.94	48.33
31.0	4.97	42.36	1.06	51.56
32.0	4.85	39.18	1.10	52.43
33.0	4.85	37.03	1.31	56.71
34.0	4.84	35.52	1.37	57.78
35.0	4.86	37.43	1.28	56.15
36.0	4.80	38.10	1.22	54.99
37.0	4.82	37.88	1.22	55.03
38.0	4.83	37.43	1.20	54.53
39.0	3.20	32.67	0.80	44.48
40.0	2.44	30.27	0.63	38.54
41.0	4.30	35.46	1.10	52.36
42.0	5.16	38.20	1.31	56.73

Table 6: Comparison of the major cation concentrations in the present study with the Jordanian allowable limits for the use of reclaimed water for irrigation purposes (2006).

Parameter	Allowable limit (mg/l)	Range of the results in the present study	Percentage of the samples above the Jordanian allowable limits	Percentage of the samples within the Jordanian allowable limits
Sodium (Na)	230	58.7 – 268.9	19 %	81 %
Potassium (K)	----	4.0 – 33.0	----	----
Magnesium Mg)	100	23.1 – 56.5	0 %	100 %
Calcium Ca)	230	56.6 – 140.2	0 %	100 %
Sodium absorption ratio (SAR)	9	1.38 – 5.20	0 %	100 %

REFERENCES

[1] Abu-Hilal, A.H. and Abualhaija, M.M., 2010. Nutrients in water and sediments of King Talal Dam-Jordan. Jordan Journal of Biological Sciences, 3(3): 87-100.

[2] Allison, L., Brown, J., Hayward, H. and Richards, L., 1968. Diagnosis and improvement of saline and alkali soils. Oxford And Ibh Publications; New Delhi; Bombay.

[3] Ayer, R. and Westcot, D., 1985. Water quality for agriculture, irrigation and drainage. Paper no, 29.

[4] Bandel, K. and Salameh, E., 1979. Pollution of the water of the Amman-Zarqa area (Jordan). German Agency for Technical Cooperation (GTZ). Germany.

[5] Bandel, K. and Salameh, E., 1981. Hydrochemical and hydrobiological research of the pollution of the waters of the Amman Zerka area (Jordan). German Agency for Technical Cooperation (GTZ). Germany, 1-60 pp.

[6] Bouwer, H., 1978. Groundwater hydrology, 480. McGraw-Hill New York.

[7] Burger, F. and Celkova, A., 2003. Salinity and sodicity hazard in water flow processes in the soil. PLANT SOIL AND ENVIRONMENT, 49(7): 314-320.

[8] Deshpande, S. and Aher, K., 2012. Evaluation of groundwater quality and its suitability for drinking and agriculture use in parts of Vaijapur, District Aurangabad, MS, India. Research Journal of Chemical Sciences 2(1): 25-31.

[9] Gupta, S.K. and Gupta, I., 1987. Management of saline soils and waters. Management of saline soils and waters.

[10] Handa, B., 1969. Description and classification of media for hydro-geochemical investigations, Symposium on ground water studies in arid and semiarid regions, Roorkee.

[11] Hem, J.D., 1985. Study and interpretation of the chemical characteristics of natural water, 2254. Department of the Interior, US Geological Survey.

[12] Karanth, K., 1987. Ground water assessment: development and management. Tata McGraw-Hill Education.

[13] Kelley, W., 1946. Permissible composition and concentration of irrigation water, Proceedings of the American Society of Civil Engineers, pp. 607-613.

[14] Kelley, W., 1963. USE OF SALINE IRRIGATION WATER. Soil science, 95(6): 385-391.

[15] Kirkby, E. and Mengel, K., 1976. The role of magnesium in plant nutrition. Journal of Plant Nutrition and Soil Science, 139(2): 209-222.

[16] Ministry of Environment, 2006. a proposal for restoration of the Zarqa River, the integrated environmental management of the Zarqa River. The Hashemite Kingdom of Jordan: P: 1-50.

[17] Mohammad, A.H., Almomani, T. and Alhejoj, I., 2015. Groundwater Vulnerability for the Surface Outcropping Aquifers in Jordan. Journal of Environmental Protection, 6(03): 250.

[18] Mohammad, A.H., Shatanawi, K. and Odeh, T., 2016. A modified modeling of potentiality and vulnerability of the groundwater resources in Amman Zarqa Basin, Jordan. Kuwait Journal of Science, 43(1).

[19] Nikanorov, A. and Brazhnikova, L., 2009. Water chemical composition of rivers, lakes and wetlands. Types and properties of water, 2: 42-80.

[20] Priyadarshi, N., 2005. Sodium in Natural Waters, Water Encyclopedia. John Wiley & Sons, Inc.

[21] Raghunath, H., 1987. Groundwater, 2" edition. New Age International Publishers, New Delhi.

[22] Rao, N.S., 2006. Seasonal variation of groundwater quality in a part of Guntur District, Andhra Pradesh, India. Environmental Geology, 49(3): 413-429.

[23] Rice, E., Baird, R., Eaton, A. and Clesceri, L., 2012. APHA (American Public Health Association): Standard method for the examination of water and wastewater. Washington DC (US): AWWA (American Water Works Association) and WEF (Water Environment Federation).

[24] Richards, L.A., 1954. Diagnosis and improvement of saline and alkali soils. U.S. Dept. of Agriculture, Washington, D.C.

[25] RSS, 1984-2004. Study on environmental pollution: preliminary study on Zarqa River. Royal Scientific Society (RSS), Amman, Jordan.

[26] Shammout, M.a., Shatanawi, M. and Naber, S., 2013. Participatory optimization scenario for water resources management: a case from Jordan. Water resources management, 27(7): 1949-1962.

[27] Shatanawi, M. and Shammout, M., 2011. Supply-Demand Modeling of Water Resources in Zarqa River Basin in Jordan. International Journal of Applied Environmental Sciences (IJAES), 6(3): 261-278.

[28] Shatanawi, M., Shammout, M. and Naber, S., 2008. Water conflicts among sectors and environmental uses in Jordan. OPTIONS Méditerranéennes, Mediterranean Seminars, water culture and water conflict in the Mediterranean area, Series A 83: 159–172, Tunisia.

[29] Todd, D., 1980. Groundwater hydrology Jon Wiley & Sons Inc, New York: 535.

[30] Weiner, E.R., 2012. Applications of environmental aquatic chemistry: a practical guide. CRC press.

[31] Wilcox, L., 1955. Classification and use of irrigation water. US Department of Agriculture, Washington, DC,(969): 19.