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Assessment of Groundwater Quality in the Faria Catchment, Palestine

تقييم جودة المياه الجوفية في حوض الفارعة، فلسطين

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Abstract

As for the entire West Bank, Palestine including Faria catchment, groundwater is the sole available and utilizable water resource. The groundwater aquifer system of the Faria catchment is utilized through springs and wells. However, groundwater quality in the catchment are deteriorating due to the effluent of untreated wastewater from urban areas and the seepage from rural cesspits in addition to uncontrolled agricultural practices. This situation has compiled the dire need to assess the suitability of groundwater for drinking and agricultural purposes in the Faria catchment. Monitoring, sampling, and testing of chemical, physical and microbial parameters for selected groundwater wells and springs in the Faria catchment were conducted during the period from December 2010 to September 2013. As much as 123 samples were collected and analyzed for various parameters, comprising SO_4^{-2}, NO_3^-, HCO_3^-, K^+, Na^+, Ca^{+2}, Mg^{+2}, Cl^{-1}, total dissolved solids (TDS), electrical conductivity (EC), acidity (pH) and Fecal Coliform (FC). The results showed that some of the tested chemical parameters exceed the desirable limits, though most of the tested parameters are within the highest permissible limit for drinking water. Induced pollution from anthropogenic nature was detected. Additionally, FC bacteria were detected in groundwater wells and springs, which indicate the impermissible use of groundwater without disinfection for drinking purposes. Based on EC as salinity hazard and SAR as alkalinity hazard, the obtained results indicate the permissible use of groundwater for irrigation purposes in the Faria catchment.

Key words: Groundwater quality deterioration, groundwater quality assessment, untreated wastewater, uncontrolled agricultural activities, Faria catchment and Palestine.

ملخص

تعتبر المياه الجوفية المصدر الرئيسي المتوفر للاستخدام في حوض وادي الفارعة كما هو الحال في الضفة الغربية، والتى يتم الحصول عليها إما من خلال الآبار الارتوازية او الينابيع. والملاحظ فإن نوعية المياه الجوفية في الحوض في تدهور مستمر وذلك بسبب تدفق مياه المجاري غير المعالجة من المناطق الحضرية او استخدام الحفر الامتصاصية في المناطق الريفية. اضافة الى الممارسات الزراعية الخاطئة كاستخدام الاسمدة والمبيدات بكميات كبيرة. ونتيجة لذلك فإن هناك ضرورة ملحة لتقييم نوعية المياه الجوفية في حوض وادي الفارعة، ودراسة ملاءمتها للشرب أو الري. ولتحقيق ذلك فقد قمنا بعمل فحوصات كيميائية وفيزيائية وبيولوجية لبعض الآبار الارتوازية والينابيع وذلك خلال الفترة ما بين كانون اول 2010 وايلول 2013. حيث تم أخذ 123 عينة واجريت لها الفحوصات المخبرية لعدد من العناصر متضمنا الفوسفات، النيترايت، البايكربونات، البوتاسيوم، الصوديوم، الكالسيوم، المغنيسيوم، الكلورايد، مجموع العناصر الذائبة، الموصلية الكهربائية، درجة الحموضة، وبكتيريا القولون الغائطية. أظهرت النتائج ان معظم العناصر الكيميائية التي تم فحصها هي ضمن المعايير المسموح بها للشرب مع وجود بعض العناصر التي تجاوزت الحد الاقصى لبعض العينات في بعض الآبار الارتوازية. كذلك تم الكشف عن التلوث الناتج عن النشاطات البشرية، حيث وجد ان بكتيريا القولون الغائطية قد تجاوزت الحد المسموح به في مياه الشرب في معظم عينات الينابيع والآبار، بما يفيد بعدم السماح لاستخدام المياه الجوفية في حوض وادي الفارعة لاغراض الشرب دون القيام بعملية التطهير. واخيرا فإن النتائج التي تم الحصول عليها تشير إلى امكانية استخدام المياه الجوفية لأغراض الري في حوض وادي الفارعة إعتماداً على الموصلية الكهربائية كمؤشر لخطر الملوحة ونسبة الامتزاز كمؤشر لخطرالقلوية.

الكلمات المفتاحية: تدهور نوعية المياه الجوفية، تقييم نوعية المياه الجوفية، المياه العادمة غير المعالجة، الممارسات الزراعية الجائرة، حوض الفارعة، فلسطين.

1. Introduction

In arid and semiarid regions and in the absence of perennial surface water, groundwater is often the only reliable and renewable source of fresh water for human beings life and development (Abdin, 2006). However, groundwater quality is being questionable due to the induced of point and nonpoint pollution sources (Almasri & Kaluarachchi, 2004). Thus, a better understanding of groundwater quality is essential in determining its suitability for different purposes (Al-ahmadi & El-Fiky, 2009; Shadeed, & *et al.* 2011).

In the West Bank, groundwater is considered to be the most precious natural source of fresh water that is used in different purposes (UNEP, 2003). However, groundwater quality is being deteriorated due to the continuous discharge of untreated wastewater from Palestinian cities, villages and Israeli colonies into receiving waters in addition to uncontrolled agricultural practices (e.g. the intensive use of agrochemicals) (Wishahi & Awartani, 1999; UNEP, 2003). Consequently, pollution of groundwater can create serious health risks to the population that relies on this source of water for different uses (UNEP, 2000).

There are several studies that documented and discussed groundwater quality in the West Bank. Among which; Wishahi and Awartani (1999), Abdul-Jaber, & *et al.* (1999), Abed Rabbo, & *et al.* (1999), UNEP (2003) Zayed, & *et al.* (2005), Awadallah & Owaiwi (2006), Shalash & Ghanem (2008), Dagrah (2009), Anayah & Almasri (2009), Ghanem & Ghannam (2010) and Shadeed, & *et al.* (2011). Most of the previous studies concluded that groundwater in the West Bank is generally considered to be of good quality in terms of chemistry but not in terms of microbiology.

In the Faria catchment, evidence of different contamination levels of groundwater wells and springs was proven (Shadeed, & *et al.* 2011). Thus, local peoples who rely on groundwater as the main drinking water source are exposed to chemical and microbial hazards (Shadeed, & *et al.* 2011; Abu Hijleh, 2014).

The main objective of this research is to determine the pollution level of groundwater aquifer in the Faria catchment in reference to physical, chemical and microbial parameters. In the catchment, groundwater wells are officially classified by PWA into domestic and agricultural wells. In reality, both types in addition to springs are used for domestic and agricultural purposes. As such, water quality of the tested springs and wells were assessed in term of suitability for drinking and irrigation purposes. In general, the analysis and assessment furnished herein is an attempt to improve our understanding to the contamination extent of groundwater in the Faria catchment. This in turn will help planners and decision makers to develop and adopt practical management strategy to protect groundwater aquifers in the West Bank.

2. Description of the Study Area

The Faria catchment is one of the major arteries draining into the Lower Jordan River. Geographically, it is located in the northeastern part of the West Bank, Palestine, and has a total area of about 320 km^2, accounting for 6% of the total area of the West Bank (Shadeed, 2008) (see **Figure 1**). Faria catchment is an important agricultural area as a part of the Jordan Valley which partially supplies the West Bank with its requirements of vegetables (Shadeed, 2007). Ground surface elevation in the catchment varies from about 900 m (amsl) at Nablus Mountains to about -350 m (bmsl) at the confluence with the Jordan River. The water in the catchment flows through a stream of an irregular shape and direction and it is generally from west to east. The catchment is of arid to semi-arid climate, which characterized by mild rainy winters and moderately dry and hot summers (Shadeed, 2008).

The magnitude of rainfall in the catchment varies with space and time. Rainfall generally decreases from west to east, where relatively high rates are usually recorded at the western boundaries of the catchment at Nablus. The rainfall distribution within the catchment ranges from 640 mm at the headwater to 150 mm at the outlet to the Jordan River. Runoff occurs as flash floods associated with heavy short-duration rainstorm events. Transmission loss is high in the catchment. As such, considerable amount of the generated runoff is lost by infiltration through highly permeable alluvial bed of the wadi channel, where possible recharge of the underlying shallow aquifer can occur (Shadeed, 2008).

In the catchment, there are about seventy groundwater wells; most of them are agricultural, some are domestic, and the remaining are Israeli-controlled wells. Also, there are thirteen fresh water springs in the catchment (Shadeed, & *et al.* 2011). Most of groundwater wells in the Faria catchment were drilled in the vicinity of the main wadi where quaternary is the main geological formation (see **Figure 1**). The main typical lithology of this formation includes gravels and alluvium (Abboushi, 2013). As such, groundwater in the catchment is mostly extracted from a shallow alluvial unconfined aquifer where the depth to water table ranges between 5 and 100 m below the ground surface (Abboushi, & *et al.* 2014). In the catchment and as for most of the aquifer systems in the West Bank, shallow groundwater depth and the presence of highly permeable overlying alluvial deposits increase the aquifer vulnerability to contamination from human activities such as the use of cesspits and uncontrolled agricultural practices (UNEP, 2003).

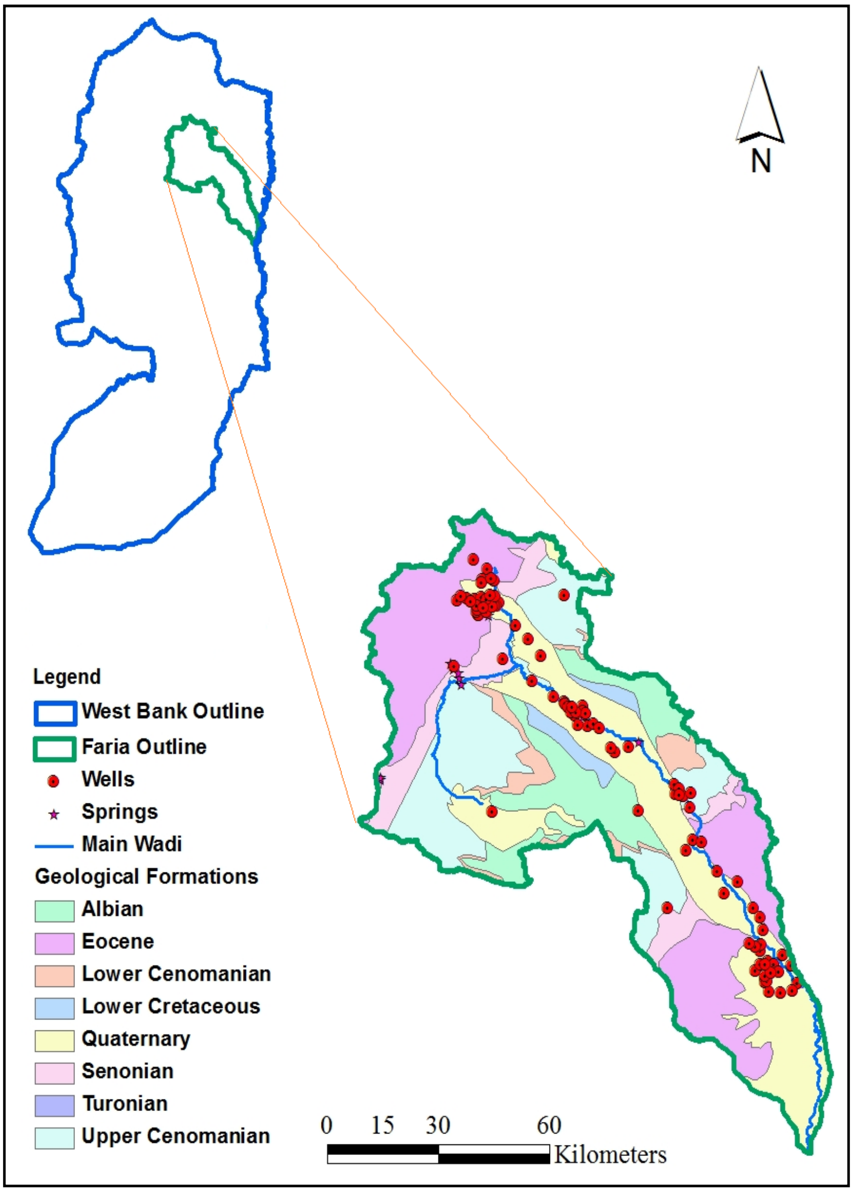

Figure (1): Location map of the Faria catchment, the distribution of wells and springs, the main wadi and geological formations.

3. Materials and Methods

Groundwater samples were collected from nine points; two springs and seven wells. Wells sampling points were selected in areas of high potential vulnerability to contamination located either closely to the main wadi where untreated wastewater is flowing such as at An-nassariya (W1 and W2) or at areas where uncontrolled agricultural activities are practiced such as at Ras El-Faria (W3, W4 and W5) and Sahl Smait (W6 and W7) (see **Figure 2**). Depth to water table for the selected wells ranges between 5 and 50 m. The two sampling points of springs were selected at Al-Bathan (S1) where cesspits are commonly used for wastewater disposal and Ein Shibli (S2) where the untreated wastewater running in the proximity of the spring mouth. The samples were collected according to prerequisite for the analysis. The collected samples were analysed at the WESI laboratories of An-Najah National University.

For the selected springs and wells, about 123 water samples were collected over two periods. In the first one (from December 2010 to May 2012) water samples were taken for S1, S2, W1 and W2 while in the second one (from October 2012 to September 2013) water samples were taken from W3, W4, W5, W6 and W7. For each location, the parameters analyzed included; SO_4^{-2}, NO_3^-, HCO_3^-, K^+, Na^+, Ca^{+2}, Mg^{+2}, Cl^{-1}, TH, TDS, EC, pH and FC. The analysis of these parameters was performed according to the standard methods of water examination (APHA, & *et al.* 2005). Electrical conductivity EC was measured in the lab after sample collection using EC meter and its value was used to calculate TDS using the relation TDS = 0.64 EC (e.g. Lloyd & Heathcote, 1985). Acidity pH was measured in the lab using pH meter. NO_3 and SO_4 were determined calorimetrically, HCO_3 was determined by titration with standard solution of HCl. K and Na were determined using flame photometer, Ca and Mg were determined by compleximetric titration with EDTA. Sampling was scheduled to be in the morning before noon for all samples and the samples were collected in the same sequence each time. Anions and cations were determined in three replicates to get reproducible results. Duplicate results did not differ by more than 5% of the mean.

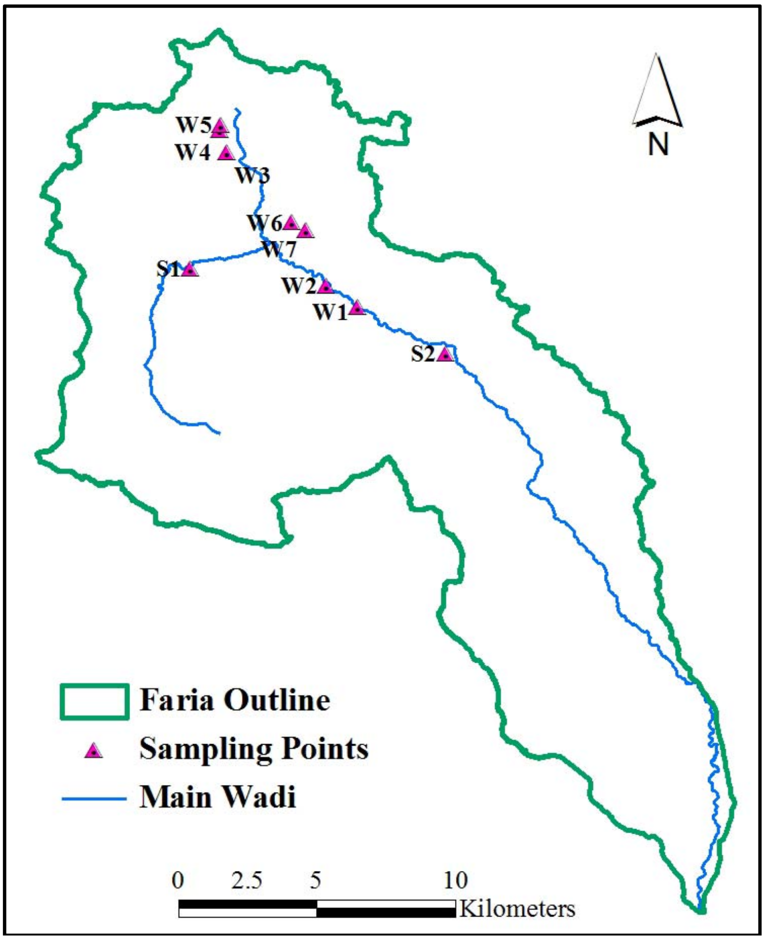

Figure (2): Location map of sampling points.

4. Results and Discussion

4.1 Suitability of Groundwater for Drinking Purposes

The average values of analytical results of chemical, physical and microbial parameters of the different groundwater samples are summarized in **Table 1**. However, to assess the suitability for drinking, the obtained parameters of the tested groundwater springs and wells were compared with the local Palestinian drinking water standards (PSI, 2005) and WHO standards (2011) (see **Table 1**).

From the table, a range of variations exist in the tested parameters of groundwater for different locations. Furthermore, it is obvious that some of the tested chemical parameters exceed the desirable limits of Palestinian and WHO standards, though it is within the highest permissible limit except nitrate. W4 and W5 (located at Ras Al-Faria), had nitrate concentration above the highest permissible limit where concentration reaches 81mg/L in some samples. This can be attributed to the uncontrolled agricultural practices (e.g. excessive use of chemical fertilizers and manures). As such, health of people how use these wells as a source for drinking is threaten. This result is good matched with the result of Anayah & Almasri (2009) were most of the annual maximum nitrate concentrations in groundwater for the entire West Bank was above the maximum desirable limit. Generally, several diseases such as methemoglobinemia, gastric cancer, goiter, birth malformations, and hypertension can be attributed to high concentrations of nitrate (Majumdar & Gupta, 2000). Concentrations of sulfate are found within the desirable limits of 200 mg/L. However, higher concentration of sulfate in drinking water is associated with respiratory problems (Subba Rao, 1993).

The present of HCO_3 and Cl in drinking water have no known harmful health effects; however, it should not exceed the desirable limit of 200 and 250 mg/L, respectively. Higher concentration of Cl in drinking water causes a salty taste and has a laxative effect in people not accustomed to it (Bhardwaj & Singh, 2011). Results show that HCO_3 exceeds the desirable limit in about 96% of the samples while Cl is below the desirable limit in 121 out of 123 samples. High concentration of bicarbonates in most of the groundwater samples might be attributed to the continuous effluent of untreated wastewater in the catchment. Higher concentration of Cl in drinking water causes a salty taste and has a laxative effect in people not accustomed to it (Bhardwaj & Singh 2011).

Sodium concentration was in the range of 9 to 87 mg/L for all sampling locations which are within the desirable limit of 200 mg/L.

However, a higher sodium concentration in drinking water may cause hypertension, congenial heart diseases, and kidney problems (Dahl, 1960). Concentrations of Mg are also found within the maximum desirable limit for most of samples.

On average, concentrations of Ca are exceeded the maximum desirable limit for about 40% of samples. High concentrations of Ca and Mg will increase total hardness of groundwater. Exposure to hard water has been suggested to be a risk factor that could exacerbate eczema (WHO, 2009).

The average concentration value of EC is exceeded the desirable limit of 750 μS/cm. However, EC values were exceeded the limit in 49 out of 123 samples. The higher EC values may cause a gastrointestinal irritation in the consumers (Howard & Bartram, 2003). TDS values in the catchment vary in the range of 243 to 823 mg/L which is within the maximum desirable limit of 1000 mg/L. For all sampled wells and springs, the pH values were in the range of 6.8 to 9.4 yet are within maximum permissible limit, but they indicate an alkaline type of groundwater.

Finally, results of the microbial analyses indicate that the sampled springs and wells were highly contaminated. For S1 (spring located in the upper part of the catchment, at residential area of Al-Bathan village) the source of increased levels of microbial contamination could be due to seepage from wastewater cesspits, whereas the source of microbial contamination of S2 (Shibli spring) could be explained by the untreated wastewater flowing in the nearby wadi and cesspit in Ein-Shibli park. This is comparable with the result of Abed Rabbo, & *et al*. (1999) in which the authors concluded that most of springs in the West Bank are contaminated with FC bacteria. Microbial contamination of wells (W1 and W2) might be attributed to the flowing of untreated wastewater in the wadi where these shallow wells were drilled in the vicinity of the polluted wadi. For wells (W3, W5 and W6) few counts of FC were detected. This can be attributed to the use of manures as these wells located at agricultural areas either at Ras Al-Faria or Sahl Smait. This in turn indicates the infiltration of pollutants in the recharge area of the wells through the highly permeable overlying alluvial deposits.

Table (1): Average values of chemical, physical and microbial parameters of the tested springs and wells in the Faria catchment and Palestinian and WHO standards for drinking water.

Sample ID	**# of Samples**	**Parameters**											
		SO_4^{-2}	**NO_3^-**	**HCO_3^-**	**Cl^-**	**Mg^{+2}**	**Ca^{+2}**	**Na^+**	**K^+**	**TDS**	**EC**	**pH**	**FC**
S1	19	7.6	17	261	47	14	78	17	3.4	325	507	7.9	2443
S2	18	8.6	20	304	112	28	84	19	4.1	445	707	7.4	247
W1	15	5.7	21	302	116	32	94	19	2.9	522	816	7.3	163
W2	15	6.3	21	315	95	33	85	19	3.1	486	759	7.4	179
W3	11	0.3	23	309	79	15	118	28	1.2	429	670	7.3	1
W4	12	0.3	35	289	79	18	125	28	1.1	453	708	7.5	0
W5	10	0.5	39	281	89	20	127	34	1.3	490	766	7.3	9
W6	12	0.2	19	313	199	34	116	72	1.9	673	1051	7.5	2
W7	11	1.4	21	299	122	35	101	44	2.0	511	799	7.5	0

… Continue table (1)

Sample ID	# of Samples	SO_4^{-2}	NO_3^-	HCO_3^-	Cl^-	Mg^{+2}	Ca^{+2}	Na^+	K^+	TDS	EC	pH	FC
		Parameters											
Range		0–36.3	12–81	122–407	18–288	0–66	60–172	9–87	0.6–11.3	243–823	380–1286	6.8–9.4	0–7600
Average		3.4	24	297	104	25	103	31	2.3	482	754	7.4	338
Palestinian Standards	Maximum Desirable	200	50	200	250	50	100	200	10	1000	750	6.5–8.5	0
	Highest Permissible	400	70	600	600	120	200	400	12	1500	1500	9.5	0
WHO Standards	Maximum Desirable	200	-	200	250	30	75	50	100	500	750	7–8.5	0
	Highest Permissible	600	50	600	600	150	200	200	200	1500	1500	6.5–9.2	0

Values of ions in mg/L, EC (μS/cm), TDS (mg/L).

4.2 Suitability of Groundwater for Irrigation Purposes

Good quality of water has the potential to cause better crop yields under good soil and water management practices. The suitability of irrigation water depends upon many factors including the quality of water, soil type, salt tolerance characteristics of plants, climate and drainage characteristics of soil (Michael, 1990).

Salinization is the major cause of loss of crop production and is one of the most abundant adverse environmental impacts associated with irrigation. Saline conditions severely restrict the choice of crops, adversely affect the crop germination and yields, and can pollute the soils (Bhardwaj & Singh, 2011).

The salts, besides affecting the growth of plants directly, also affect the soil structure, permeability, and aeration, which indirectly affect the growth of plant. Irrigation water containing a high proportion of sodium will increase the exchange of sodium content of the soil, affecting the soil permeability and texture. This makes the soil difficult to plough and unsuitable for seeding emergence (Triwedy & Goel, 1984). The sodium percentage (Na%) in the water samples is calculated by the following equation:

$$Na\% = \frac{Na}{Ca + Mg + Na + K} \times 100\%$$,where all concentrations are in meq/L.

If the percentage of sodium presence is high in irrigation water, calcium and magnesium exchange with sodium, thus causing deflocculation and impairment of the plowing and permeability of soils (Karanth, 1987). However, the classification of groundwater was grouped based on percentage of sodium as Excellent (<20 %), Good (20-40 %), Permissible (40-60%), Doubtful (60-80%) and Unsuitable (> 80%), (Sadashivaiah, & *et al.* 2008). The sodium percentage (Na%) in the tested wells and springs ranges between 5 and 35%, with an average value of about 15%. This in turn indicates that the groundwater in the Faria catchment have good to excellent irrigation water.

The sodium adsorption ratio (SAR) is also used as an index to determine water suitability for irrigation in accordance with EC. SAR can be estimated by the formula:

$$SAR = \frac{Na}{\sqrt{\frac{(Ca+Mg)}{2}}}$$, where all concentrations are in meq/L.

The classification of irrigation water with respect to SAR is mainly based on the effect of exchangeable sodium on the physical condition of the soil. Sodium sensitive crops can be damaged due to the accumulation of sodium in plant tissues. Excellent/low sodium water (SAR = 0–10), good/medium sodium water (SAR = 10–18), doubtful/high sodium water (SAR = 18–26) and unsuitable/very high sodium water (SAR > 26). Based on EC values, irrigation water is classified into four classes: excellent/low (EC ≤ 250 μS/cm), good/medium (250–750 μS/cm), doubtful/high (750–2250 μS/cm), and unsuitable/very high (2250–5000 μS/cm), (Richards, 1954; Wilcox, 1955; Sadashivaiah, *et al.* 2008). Thus and based on EC and SAR, the Wilcox classification diagram illustrated in **Figure 3** has been used to identify the suitability of the tested wells and springs for irrigation purposes. Based on the figure, all the tested wells and springs were clustered in two fields (C2-S1 and C3-S1) indicating medium to high salinity hazard and low sodium hazard.

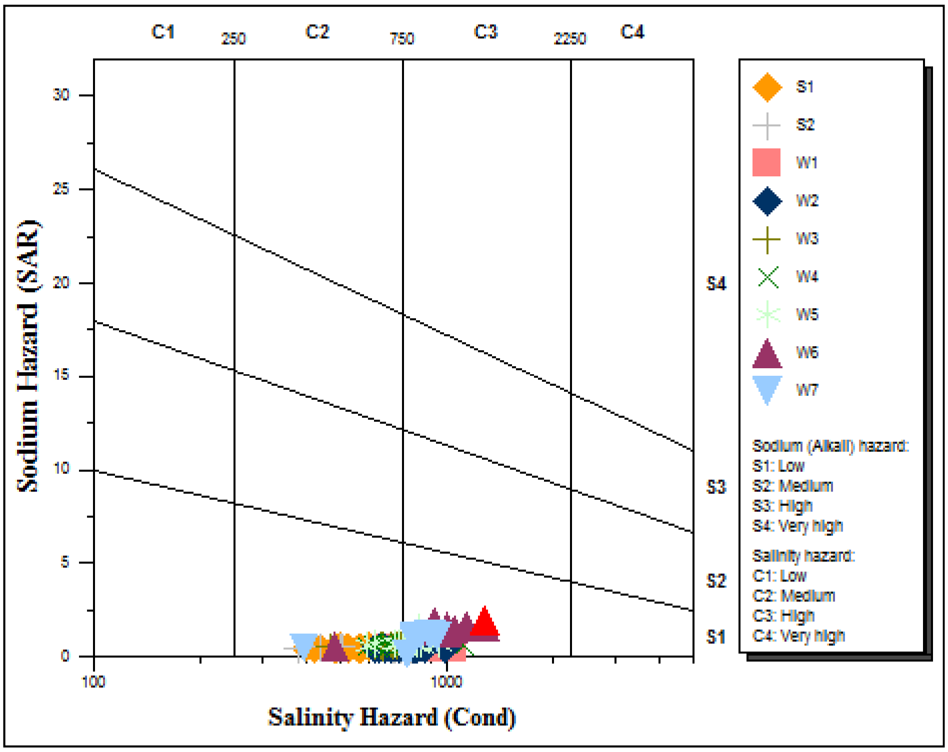

Figure (3): Wilcox diagram for the tested springs and wells.

5. Conclusions

Groundwater quality in the Faria catchment was studied to assess its suitability for drinking and irrigation purposes. The chemistry of tested groundwater wells and springs can be used as the background water quality criteria for the evaluation of groundwater quality in the Faria catchment. The groundwater chemistry, of the tested wells and springs indicated that small variations exist within each parameter. The overall groundwater quality of the study area is suitable for drinking purposes in terms of chemistry except for nitrate where the concentration exceed the maximum desirable limit in some samples. In addition, detected FC values in the tested wells and springs were unacceptable and make it unsafe for drinking purposes. Accordingly, local communities which are being used such sources for drinking subjected to water-borne diseases in absence of disinfection processes. In general, the obtained results are very comparable with most of previous studies which concluded that groundwater in the West Bank is generally considered to be of good quality in terms of chemistry but not in terms of microbiology. Wilcox diagram values of EC as salinity hazard and SAR as alkalinity hazard, indicate that groundwater in the Faria catchment have medium to high salinity and low alkalinity. Hence, it can be used for irrigation with less negative impacts. Groundwater quality assessment presented in this study will be of great importance for decision makers to adopt sustainable water resources management strategies in the Faria catchment.

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