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Water Quality Study of Wadi Al Qilt-West Bank-Palestine*

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Abstract: This study was conducted due to the lack of water quality data about Al Qilt drainage basin. Twenty water samples from the five springs in Al Qilt drainage basin were analyzed to determine their quality. Chemical, physical and biological studies were conducted between November (2004) and March (2007) in Wadi Al Qilt drainage basin. Based on physical parameters, the water flowing from the springs is considered as good source of drinking water. According to the results of SAR and TH, the water is classified as suitable source for domestic, industrial and agricultural purposes. Results showed moderate levels of major ion and higher concentrations of lead and cadmium than allowable for drinking water in three spring samples, whereas, 47% of the samples were contaminated with fecal coliforms, which indicate the infiltration of pollutants in the recharge area of the springs.

Key words: Hydrochemistry, Al Qilt drainage basin, springs, water types

INTRODUCTION

Water is an extremely important issue, not only in the Middle East, but also in every community in the world. Without water there is no life. The scarcity of the water resources in the West Bank and Gaza Strip, due to arid to semi-arid climate, over exploitation, mismanagement and their pollution as well as the fact that these resources are shared with Israel, gave it a great importance. In addition to the arid to semi-arid climate, high population growth and the lack of sewer systems, which results in the infiltration of wastewater into groundwater resources causes water resources pollution. Groundwater is considered to be the main fresh water resource in the West Bank. There are three main basins in the West Bank, the north-eastern, the western and the eastern basins (Fig. 1). The crest of the anticlinal structure of the Mountain Aquifer acts as the watershed for groundwater flowing westwards to the Mediterranean or eastward to the Jordan Valley and Dead Sea (Abed Rabbo *et al*., 1999). Due to the rapid increase of population which can be referred to natural growth and the increasing number of Israeli settlements, the demand for potable water in West Bank for domestic uses has increased in the last two decades. Water quality of groundwater and some West Bank springs were studied and an annual increment in pollutants was reported by Alawneh and Al-Sàed (1997) and Shalash and Ghanem (2008).

Jericho water resources are part of the Eastern Aquifer Basin. Groundwater sources in Jericho district are mainly divided between wells and springs. The main system in the area is Wadi Al Qilt system that has a catchment area stretching out from the Jordan River in the east towards Jerusalem and Ramallah in the west. This system is fed from three main springs Ein Fara, Ein Al Fawwar and Ein Al Qilt (Rofe and Raffety, 1965). The system of Wadi Al Qilt springs is the main water source for the Jericho Water Treatment Plant (JWTP). Water is

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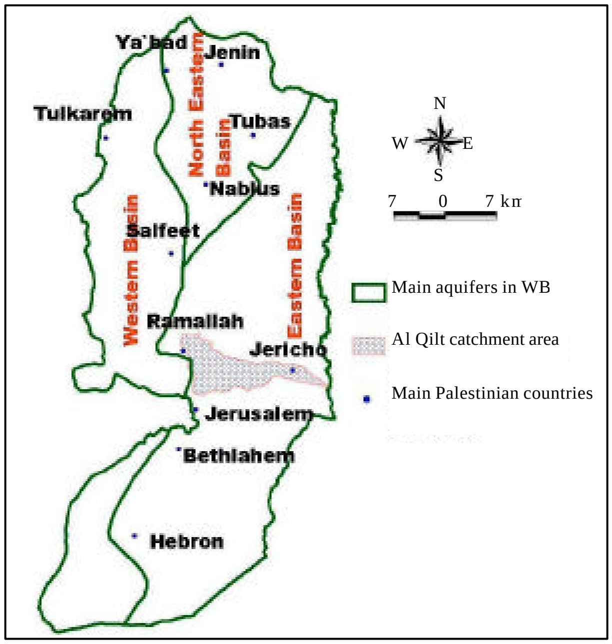

Fig. 1: Location of Al Qilt drainage basin

transported from springs to the treatment facility through a 13 km long open transportation canal. The drainage basin of Wadi Al Qilt was chosen for the present study as there is a lack of data for this system. Secondly, evidence of pollution from many springs in this basin as well as the sewage flow along the wadi is a potential health hazard for the local inhabitants and users downstream.

The main aim of this study is to determine the physical, chemical and biological parameters of the springs as well as to evaluate the suitability of these water resources for domestic and other uses.

Wadi Al Qilt is located in the eastern part of the West Bank (Fig. 1). Surface and subsurface water of the eastern basin drain towards the Jordan Valley. Surface water comprises the flood flows during winter season and the base flow of springs, which mainly originate in the western mountainous area (Wishahi and Khalid, 1999). The study area includes part of Ramallah, Al Bireh and Jerusalem (comprises the western part of the study area) and part of Jericho (comprises the eastern part). It represents the major drainage system from the mountain aquifer area between Jerusalem and Ramallah downwards east to the Jordan River with an area of 174.7 km^2. Wadi Al Qilt drainage basin is bounded by Nueima drainage basin from north, Soreq and Al Dilb drainage basins from west, Mukallak and Marar drainage basins from south and Jordan River from the east. This catchment, that drains part of the Ramallah and Jerusalem Mountains, is a sub-basin of the Jordan River-Dead Sea basin. The drainage basin of Wadi Al Qilt is located in the well-known Dead Sea Rift Valley which has elevations in the range of 200 to 250 m.b.s.l. in the east and the west of the drainage basin, in the vicinity of Ramallah and Jerusalem the mountains rise up to elevations over 800 m.a.s.l.

There are two main tributaries in Al Qilt drainage basin in which the result of their discharge combined with the flow from the five springs form the main stream named as Wadi

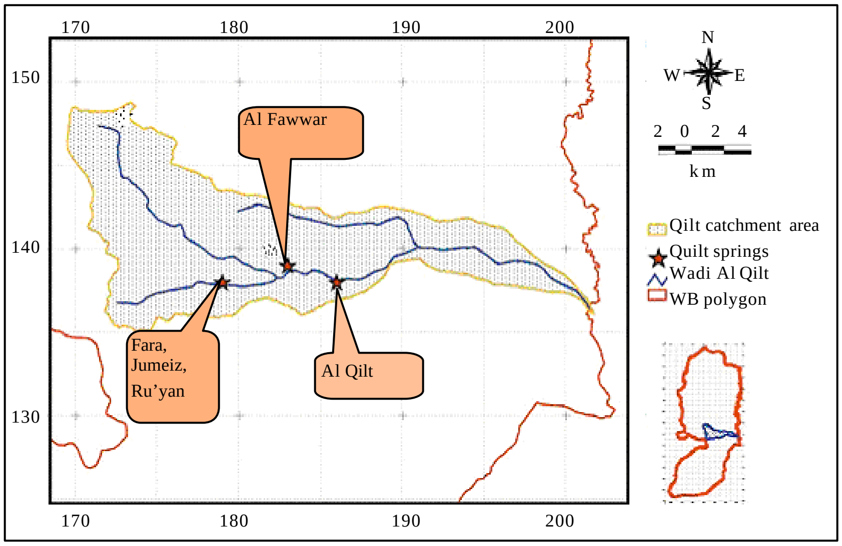

Fig. 2: Location of springs in Al Qilt drainage basin

Al Qilt. The first tributary is called Wadi Sweanit which originates from the eastern part of Al Bireh before it combines with the second tributary named as Wadi Fara (collects the flow from Ein Fara, Ein Al Jumeiz and Ein Al Ru'yan springs) (Fig. 2). There are five springs found in Wadi Al Qilt drainage basin, three of them are major springs, Ein Fara, Ein Al Fawwar and Ein Al Qilt and two are minor ones, Ein Al Jumeiz and Ein Al Ru'yan. Three of these springs, Ein Fara, Ein Jumeiz and Ein Ru'yan are found at the beginning of Wadi Fara which is separated from Wadi Sweanit that carries the effluent of Al Bireh Wastewater Treatment Plant (AWWTP). As shown in Fig. 2, the joint point of these two wadis is located before Ein Al Fawwar with around 1.5 km. Few meters separate Ein Al Fawwar from Wadi Al Qilt whereas Ein Al Qilt flows directly into the wadi.

The catchment area of Al Qilt drainage basin is about 174.7 km^2 with average annual rainfall over the main recharge area of about 80 km^2 is 500 mm. Nari reduces the effective recharge to about 42.5 km^2 (Rofe and Raffety, 1965), which represents about 21.5 mcm potentially entering the groundwater system. Of this average annual discharge from Ein Fara, Ein Al Fawwar, Ein Al Qilt and Ein es Sultan is about 9 mcm. The springs of Ein Fara, Ein Al Fawwar and Ein Al Qilt emerge from Turonian. The aquifer is of Cenomanian-Turonian age, the strata dipping eastwards at 10-15° (Fig. 3). Groundwater flow flows in the direction of dip, but the water table is at shallower angle, breaking the surface were the springs emerge. The Cenomanian consists mainly of micritic dolomite which is very hard and virtually nonporous, the void space in the rock occupying only 2.6%. This gives the dolomite an intrinsic permeability of 0.13 millidarcys, i.e., a flow rate of 39.66 mm $year^{-1}$. However, solution weathering increases the secondary porosity and, consequently actual flow increases as joints and bedding planes are widened. The Turonian is a highly fossiliferrous limestone, with fossil fragments making up 30% of the volume of the rock. The matrix is recrystallized calcite. Primary porosity, therefore, is greater than in the Cenomanian, being 8-15% of the rock. The intrinsic permeability is also greater than in the Cenomanian, being 135 millidarcys. Groundwater flow in the Turonian is up to 1.5 km $year^{-1}$, indicating the effect of karstic solution weathering in the system (Abed Rabbo, 1999). There is little variation in the

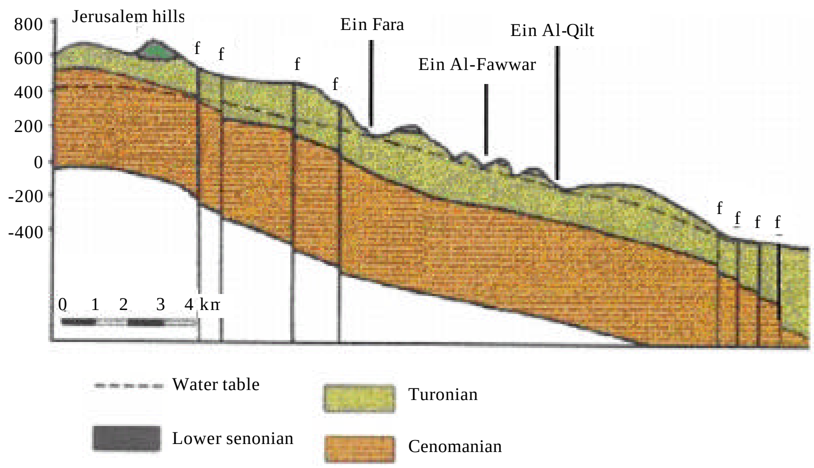

Fig. 3: Geological sketch section along the line of springs in Al Qilt (source: Abed Rabbo *et al*., 1999)

discharge of Ein Al Qilt through out the year. It may therefore be assumed that the water is under pressure and comes from a massive reservoir. The average flow of Ein Fara is 15 L sec^{-1} or 1,300 m^3 day^{-1}. The combined average discharge rate of Ein Al Fawwar and Ein Al Qilt springs are 100 L sec^{-1}. Ein Al Fawwar has a large discharge following a heavy rainfall season (Blake, 1928). The siphonic spring at Ein Al Fawwar filled the cistern which fed the channel bringing water to Al Qilt and the overflow discharges into the wadi to combine with the flow coming from Wadi Fara and Wadi Sweanit. The pulses from the spring are at 20 min cycles and used to raise the level of the cistern by as much as 2 m. The karstic nature of the spring is responsible for these pulses. A V-shape cavern is filled before siphonic discharge expels the water in these regular pulses. The water table under the Jerusalem Hills is at an elevation of about 450 m.a.s.l. The water table passes from the Cenomanian under the Jerusalem Hills into the Turonian as a result of the Fara monocline (Abed Rabbo *et al*., 1999).

Mahmoud and Al-Sáed (1997) reported that almost 40% of the total Jewish settlements in the West Bank are considered as highly risk potential pollution sources.

Water is the most precious natural resource in the West Bank and Gaza Strip. Adequate supplies of high quality water are essential for economic growth, quality of life, environmental sustainability. According to Marei *et al.* (2005), Wadi Al Qilt represents the major drainage system from the mountains area between Jerusalem and Ramallah downwards east to the Jordan Valley. The importance of Wadi Al Qilt is that part of its discharge (after the combination of discharge of all springs: Ein Fara, Ein Jumeiz, Ein Ru'yan, Ein Al Fawwar and Ein Al Qilt) is used to fed JWTP. So, it was necessary to study the water quality of the springs as their flow ends up for human and other purposes after certain treatment.

MATERIALS AND METHODS

Field Work

Whole system were recorded, especially to confirm the data collected during the interviews, to identify the existing water resources, assigning sampling stations and water sampling. Also, observations about water quality (color or odor) through the whole system were recorded.

After several field visits to the study area from November 2004 to March 2005, it was possible to choose the sites for sampling from Ein Al Qilt, Ein Al Fawwar, Ein Fara, Ein Jumeiz and Ein Ru'yan. Five sampling stations were the target of the sampling campaigns, at different times during the study period. Twenty water samples from the springs were collected and analyzed for different parameters at different dates during the study period. Sampling frequency was variable according to weather status and prevailing political situation in the study area as well as in the West Bank.

The sampling campaigns from all springs were carried out to cover the study period from November (2004) to March (2007), where the samples were analyzed directly after collection.

Water Analysis

The water analysis in the labs followed the sampling campaigns directly. The purpose of water analysis was to determine the level of water pollution of springs in Al Qilt drainage basin. The way to accomplish this purpose was through measuring the water quality parameters, chemical parameters (Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}, HCO_3^- , SO_4^{-2}, Cl^-, NO_3^-, DOC, trace elements such as Ag, Al, Ba, Cd, Co, Cr, Cu, Fe, Li, Hg, Mn, Ni, Pb, Sr, Zn, Be, Se and Mo), physical parameters (pH, turbidity, TDS, EC) and microbiological parameter (fecal or total coliform). Standard methods for the examination of water and wastewater (APHA, 1995) (19 edition) was used as a reference for all methods of analysis of all measured parameters.

Finally, a software package called Aquachem was used as a tool for the interpretation of the obtained chemical data for springs. Also, the maps for the study area were prepared using software called Geographical Information System (GIS). Interpretation of data was done using excel.

RESULTS AND DISCUSSION

Results showed little variation in the various parameters especially in EC, chloride and pH. The highest measured value for EC was for Ein Al Fawwar spring (632 µS) whereas the minimum was for Ein Al Qilt spring (478 µS). For all springs, the values of turbidity varied between 0 and 2. The highest and lowest measured values for pH were 7.7 and 6.8, respectively and both values were measured for Ein Al Fawwar spring (Table 1). The Na^+/Cl^- ratio (meq L^{-1}) ranges between 0.43 and 1.54 in all samples.

Concerning the organic content of the nine samples, TOC varies between 0.58 and 2.45 mg L^{-1} (both in Ein Al Fawwar) (Table 2). Whereas, the results showed that seven samples that were collected from Ein Al Fawwar and Ein Al Qilt were contaminated with fecal coliform bacteria but the others were free of coliform (Table 2).

Detailed heavy metal analysis of various samples representing the five springs were conducted using Perkin-Elmer Optima 3000 Inductively Coupled Plasma-Optical Emission Spectrometer, but they did not show high amounts that might cause harm. One sample from Ein Al Qilt spring shows high Lead concentration (102 µg L^{-1}) and two samples were contaminated with Zinc 87 and 93 µg L^{-1} collected on 13/03/2005 and 15/05/2005, respectively. The sample collected from Ein Al Fawwar on 15/05/2005 was contaminated with Zinc (95 µg L^{-1}).

Based on these values and historical data collected by Palestinian Water Authority (PWA) (EC around 500 µS), these springs are considered as good source of drinking water (Ghanem, 1999).

Table 1: Physical and chemical characteristics of the springs in Wadi Al Qilt

Site ID	Spring name	Sampling date	pH	EC (μS cm^{-1})	TDS (mg L^{-1})	Turbidity (NTU)	Ca (mg L^{-1})	Mg (mg L^{-1})
AS/020	Ein Al Qilt	13/03/2005	7.4	514	380	1	41	24
AS/020	Ein Al Qilt	16/04/2005	7.2	550	302	1	55	19
AS/020	Ein Al Qilt	15/05/2005	7.2	620	341	2	71	19
AS/020	Ein Al Qilt	2/4/2006	7.3	570	322	1	43	22
AS/020	Ein Al Qilt	25/03/2007	6.9	478	369	1	45	25
AS/021	Ein Al Fawwar	6/3/2005	7.7	602	470	1	47	27
AS/021	Ein Al Fawwar	13/03/2005	6.8	608	267	2	43	32
AS/021	Ein Al Fawwar	16/04/2005	7.2	632	348	2	43	-
AS/021	Ein Al Fawwar	15/05/2005	7.3	539	290	1	64	19
AS/021	Ein Al Fawwar	2/4/2006	7.2	613	370	2	52	25
AS/021	Ein Al Fawwar	25/03/2007	7.6	579	324	2	54	22
AS/022	Ein Fara	31/03/2005	7.2	573	366	0	62	21
AS/022	Ein Fara	2/4/2006	7	565	345	1	56	18
AS/022	Ein Fara	25/03/2007	7.3	615	290	1	67	25
AS/022A	Ein Al Jumeiz	31/03/2005	7.2	577	364	1	66	22
AS/022A	EinAl Jumeiz	2/4/2006	7.1	553	346	1	52	18
AS/022A	EinAl Jumeiz	25/03/2007	7.7	498	285	2	71	26
AS/022B	Ein Al Ru'yan	31/03/2005	7.1	576	362	1	62	21
AS/022B	Ein Al Ru'yan	2/4/2006	7.1	538	375	0	53	19
AS/022B	Ein Al Ru'yan	25/03/2007	7.5	623	354	1	65	28

Site ID	Spring name	Sampling date	Na (mg L^{-1})	K (mg L^{-1})	HCO_3 (mg L as $CaCO_3$)	Cl (mg L^{-1})	SO_4 (mg L^{-1})	NO_3 (mg L^{-1})
AS/020	Ein Al Qilt	13/03/2005	28	0.3	232	48	15	21
AS/020	Ein Al Qilt	16/04/2005	22	0	175	78	13	17
AS/020	Ein Al Qilt	15/05/2005	26	2	237	61	14	39
AS/020	Ein Al Qilt	2/4/2006	26	1	242	59	14	22
AS/020	Ein Al Qilt	25/03/2007	19	1	214	55	12	35
AS/021	Ein Al Fawwar	6/3/2005	26	0.1	240	86	10	34
AS/021	Ein Al Fawwar	13/03/2005	27	0	236	55	7	27
AS/021	Ein Al Fawwar	16/04/2005	31	0	167	74	17	31
AS/021	Ein Al Fawwar	15/05/2005	23	2	242	45	13	30
AS/021	Ein Al Fawwar	2/4/2006	29	0	235	62	11	32
AS/021	Ein Al Fawwar	25/03/2007	32	1	255	56	15	45
AS/022	Ein Fara	31/03/2005	23	2	237	23	15	25
AS/022	Ein Fara	2/4/2006	19	1	205	21	13	26
AS/022	Ein Fara	25/03/2007	29	1	185	44	17	36
AS/022A	Ein Al Jumeiz	31/03/2005	22	1	233	45	15	21
AS/022A	EinAl Jumeiz	2/4/2006	17	1	195	19	11	23
AS/022A	EinAl Jumeiz	25/03/2007	25	2	217	36	9	37
AS/022B	Ein Al Ru'yan	31/03/2005	23	2	194	23	13	24
AS/022B	Ein Al Ru'yan	2/4/2006	17	1	198	21	10	25
AS/022B	Ein Al Ru'yan	25/03/2007	15	1	215	26	16	31

Table 2: TOC and FC of Al Qilt springs

Spring name	Date	TOC (mg L^{-1})	FC (cfu/100 mL)
Ein Al Fawwar	06/03/2005	-	0
Ein Al Fawwar	13/03/2005	-	12
Ein Al Fawwar	16/04/2005	2.45	2
Ein Al Fawwar	15/05/2005	0.58	3
Ein Al Fawwar	02/04/2006	1.80	5
Ein Al Qilt	13/03/2005	-	3
Ein Al Qilt	16/04/2005	2.07	28
Ein Al Qilt	15/05/2005	0.96	0
Ein Al Qilt	02/04/2006	1.20	7
Ein Fara	31/03/2005	-	0
Ein Fara	02/04/2006	0.72	0
Ein Jumeiz	31/03/2005	-	0
Ein Jumeiz	02/04/2006	0.66	0
Ein Ru’yan	31/03/2005	-	0
Ein Ru’yan	02/04/2006	1.02	0

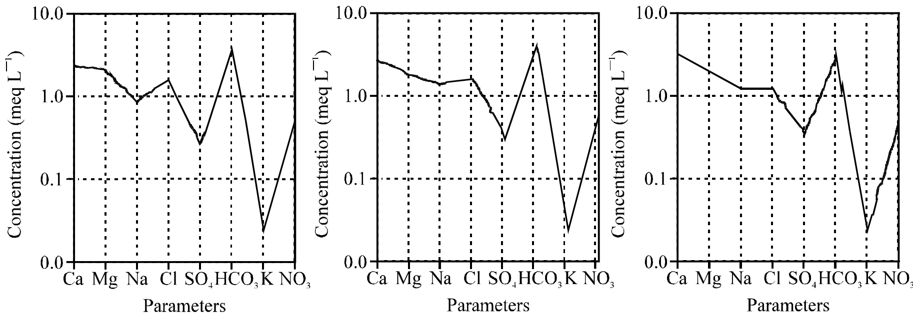

Fig. 4: Schoeller diagrams for the main springs in (a) Al Qilt drainage basin, (b) Al fawwar and (c) Fara

Table 3: Average values of saturation indices of the springs in Al Qilt drainage basin

Station ID	Spring name	SI Anhydrite	SI Aragonite	SI calcite	SI Dolomite	SI Gypsum	SI Halite
AS/020	Al Qilt	-2.83	-0.45	-0.30	-0.68	-2.59	-7.41
AS/021	Al Fawwar	-2.97	-0.34	-0.19	-0.39	-2.74	-7.34
AS/022	Fara	-2.71	-0.41	-0.27	-0.71	-2.47	-7.76
AS/022A	Al Jumeiz	-2.82	-0.23	-0.08	-0.33	-2.58	-7.74
AS/022B	Al Ru'yan	-3.26	-0.92	-0.78	-1.70	-3.03	-8.49

The values of turbidity for all springs varied between 0 and 2 which are considered below the allowable limits for drinking water (WHO, 2004). According to Metcalf and Eddyinc (1991) turbidity is used to indicate the quality of waste discharges and natural waters with respect to colloidal and residual suspended matter.

The pH of the water reflects the characteristics of the drainage basin or the underground rock strata through which the raw water has passed (Hounslow, 1995). The concentration of ions in Ein Al Fawwar spring might be affected by the human activities because the spring originates from a pond and used for swimming by settlers from around settlements.

Water quality parameters and pollution rates are affected by the human activities and agricultural processes. As indicated by Schoeller diagrams (Fig. 4a-c), the concentrations of major cations and anions recorded for the major springs do not differ with great values, which can be explained by the same nature of the geological formations. Nitrate and chloride concentrations showed high values but still lower than the maximum allowable limits (50 and 250 mg L^{-1}, respectively; Table 1) for drinking water (WHO, 2004), which indicate a washing process of pollutants by runoff over agricultural and urban areas beside the infiltration of wastewater and leachate in the upper part of the catchment's area.

The high levels of sodium and chloride are assumable to be related to contamination processes (Helena, 1998). The high ratios of sodium to chloride found in Fara and Al Ru'yan springs which reveals the probable of wastewater leakage from sewer systems and cesspits in the upper part of the drainage area.

Saturation Indices (SI)

Using Aquachem software package, average values of saturation indices (SI), listed in Table 3, for anhydrite ($CaSO_4$), aragonite ($CaCO_3$), calcite ($CaCO_3$), dolomite ($CaMg(CO_3)_2$), gypsum ($CaSO_4.2H_2O$) and Halite (HCl) were calculated for 20 samples using Aquachem 5.1. The average values of SI for all springs are below zero, which means that water is under-saturated with respect to all previous minerals. This means that the water quality of discharged water from the springs contains lower concentration of the ions and the water still has the capacity for dissolution of more minerals.

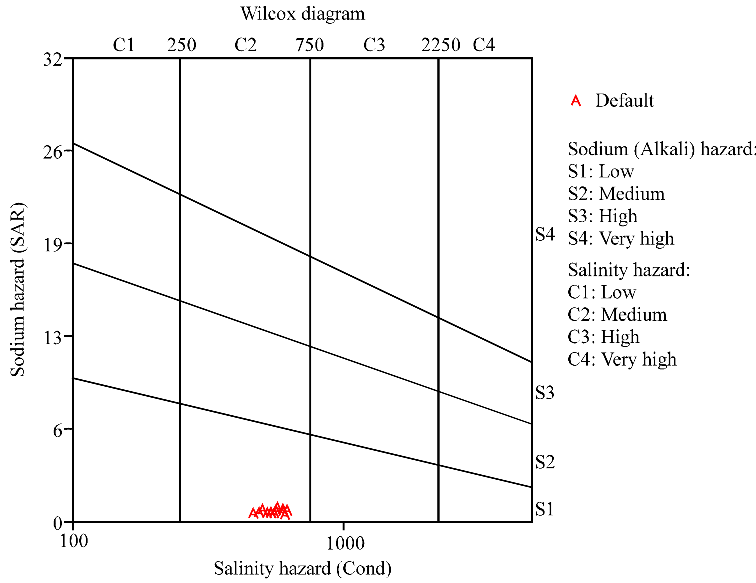

Fig. 5: Classification of Al Qilt springs water according to Wilcox

One sample from Al Ru'yan spring have SI values >0 for calcite and dolomite and one sample from each of Al Fawwar and Al Jumeiz springs have SI>0 for aragonite, calcite and dolomite, which means that they are over saturated and precipitation of aragonite, calcite and dolomite occurs.

Total Hardness (TH)

Hardness of water limits its use for industrial purposes; it causes scaling of pots and boilers, closure to irrigation pipes and may cause health problems to humans, such as kidney failure (Shalash and Ghanem, 2008).

According to Todd (1980), TH is calculated as follows:

$$TH\ (CaCO_3)\ mg\ L^{-1} = 2.497\ Ca^{+2} + 4.115\ Mg^{+2}$$

The concentrations of Ca^{+2} and Mg^{+2} are expressed in mg L^{-1}. As a water quality parameter, TH values can be used to classify water for domestic and industrial uses. In the study area, the lowest value of TH recorded was 197.99 mg L^{-1} for Al Qilt spring on 15/05/2005 and the highest value was 284.38 mg L^{-1} for Al Jumeiz spring on 25/03/2007.

Sodium Adsorption Ratio (SAR)

As the water is used downstream for drinking and irrigation purposes, Sodium Adsorption Ratio (SAR) is used as an index for sodium hazard in water for irrigation purposes in accordance with EC values. SAR is calculated according to the formula:

$$SAR = \frac{Na^{+}}{\sqrt{(Ca^{+2} + Mg^{+2})/2}}$$

where, all concentrations are in meq/l. Sodium hazard starts at values of SAR >1 and EC values >650 uS cm^{-1}, respectively (Shalash and Ghanem, 2008). The values of SAR are <1

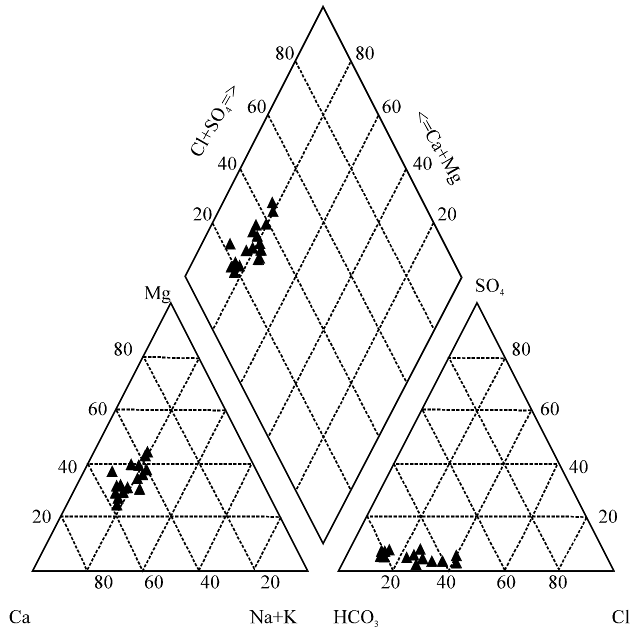

Fig. 6: Piper plot showing the water type of springs in Wadi Al Qilt

and <650 uS cm^{-1} for EC in all the springs which means that water from these springs is recommended for unrestricted irrigation. Based on EC and SAR ratio, water from Al Qilt springs can be classified for irrigation purposes according to Wilcox diagram (Fig. 5; Abed Rabbo *et al*., 1999).

Classification of Water Types using Piper Diagram

Most of the methods used for water sample grouping are based on the major inorganic dissolved constituents. No consideration is given to the organic and inorganic minor or trace constituents (Abed Rabbo *et al*., 1999).

A trilinear can show the percentage composition of three ions. So, to plot four ions from each group, two cations must be grouped (Na^+, K^+) on one axis and two anions must be grouped on the second triangle (HCO_3^-, CO_3^{2-}).

On a piper diagram, the chemical results of samples from the five springs in Al Qilt drainage basin were plotted on such diagram using special software for windows called Aquachem. According to Langguth (1966), the plot shows that these springs are located between the areas of normal alkaline water and earth alkaline water with increased portion of alkali both with prevailing bicarbonate (Fig. 6).

According to MOPIC (1998) the aquifers of West Bank are carbonate aquifers and the aquifer is of Cenomanian-Turonian age which is composed of dolomite and limestone (Abed Rabbo *et al*., 1999). However, some results show some interference of some ions such as sodium or chloride ions which cause the water type to deviate from Ca-Mg-HCO_3 (as expected for the Dolomites and limestones which characterize the aquifer which is of Cenomanian-Turonian age) to other types (Table 4).

The mean reason behind such interference is the leaching of some pollutants either from wastewater origin (cesspools, sewage systems and untreated sewage flow in the valleys) or salt deposits (from aquifer itself), especially the upper part of the drainage basin is

Table 4: Water types of groundwater from springs in Wadi Al Qilt

Spring name	Date	Water type
Ein Jumeiz	31/03/2005	Ca-Mg-HCO_3
Ein Al Qilt	13/03/2005	Ca-Mg-Na-HCO_3-Cl
Ein Al Fawwar	25/03/2007	Ca-Mg-Na-HCO3-Cl
Ein Ru'yan	02/04/2006	Ca-Mg-HCO_3
Ein Fara	25/03/2007	Ca-Mg-Na-HCO3-Cl

characterized with a lot of karstic systems. Also dissolution of solid waste combined with rainfall produce large quantity of polluted water in the form of leachate. Because of heterogeneous nature of wastes (industrial, medical and municipal wastes may generate leachate with different constituents) and variations in aquifer properties, dump sites represent a challenging opportunity to try and understand the transport and fate of waste-derived contaminants (Abu-Rukah and Al-Kofahi, 2001).

Organic Carbon and Microbiology of Springs

A main reason which may contaminate the springs is expected to be the human activities around the two springs. Also, the potential pollution sources which exist in the drainage basin such as cesspits, wastewater infiltration and the uncontrolled disposal of solid wastes might be behind the contamination of the springs.

Trace Elements in Springs

According to WHO (2004), the concentration of Lead exceeded the maximum allowable concentration in drinking water (0.01 mg L^{-1}), however for Zinc it is below the maximum allowable limit. Moreover, the concentration of Cadmium in Ein Ru'yan spring was the highest among the five springs, 36 μg L^{-1}, which also, exceeds the maximum allowable limit (3 μg L^{-1}).

CONCLUSION

According to WHO (2004), all analyzed samples for physical, chemical and biological parameters of the springs, trace elements showed a significant level of zinc but all the values were under the maximum allowable limits. However, one sample from Ein Ru'yan and one sample from Ein Al Qilt showed a high concentration of cadmium and lead respectively which exceeded the maximum allowable limits for drinking water. Ein Al Fawwar and Ein Al Qilt were microbially contaminated where the others were free. Ein Fara water is considered the most suitable source among the five springs in the basin for domestic and other uses.

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