

Assessment of the spring water quality in The Shoubak area, Jordan

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Abstract The present study investigates the physical, chemical, and biological characteristics of spring water samples in Shoubak area in the southern Jordan. The samples were collected from May 2004 to May 2005. All samples were analyzed for temperature, conductivity, dissolved oxygen, pH, major cations (Ca^{2+} , Mg^{2+} , K^+ , Na^+), major anions (Cl^- , NO_3^- , HCO_3^- , SO_4^{2-} , PO_4^{3-} , F^-), and trace metals (Fe^{2+} , Al^{3+} , Mn^{2+} , Cu^{2+} , Cr^{3+} , Ni^{2+} , Zn^{2+} , Pb^{2+} , Cd^{2+}). Water quality for available springs showed high salinity through long period of contact with rocks. The ion concentrations in the water samples were from dissolution of carbonate rocks and ion exchange processes in clay. The general chemistry of water samples was typically of alkaline earth waters with prevailing bicarbonate chloride. Some springs showed elevated nitrate and sulfate contents which could reflect to percolation from septic tanks, cesspools, and agricultural practices. The infiltration of wastewater from cesspools and septic tanks into groundwater is considered the major source of water pollution. The results showed that there were great variations among the analyzed samples with respect to their physical, chemical and biological parameters, which lie below the maximum permissible levels of the Jordanian and WHO drinking water standards. The results indicate that the trace metals of spring's water of Shoubak area do not generally pose any health or environmental problems. Factor analysis was used to identify the contributors to water quality. The first factor represents major contribution from

anthropogenic activities, while the second one represents major contribution from natural processes.

Keywords Coliform · Factor analysis · Hydrochemistry · Jordan · springs · Trace metals

1 Introduction

The quality of surface water and groundwater in the world are very sensitive issues. In general, the chemical compositions of surface and groundwater are determined by a number of processes, which include atmospheric inputs, interaction of water with soil and rock and inputs of chemical derived from anthropogenic activities such as; industrial, agriculture, increasing consumption and urban influence as well as natural effects such as changes in climate, precipitation input, weathering and erosion of crustal material that degrade surface waters and impair their use for drinking, agricultural, industrial, and domestic uses (Simionov et al. 2003; Carpenter et al. 1998; Jarvie et al. 1998; Jeong 2001). In the urban areas, there are many possible sources for groundwater contamination such as; septic tanks and cesspools, domestic and industrial effluents, landfill waste sites, leakage from sewage system and petroleum stations (Jeong et al. 2001).

The water resources in Jordan consist of groundwater and fossil water which extends in aquifers at different depths through country. Groundwater is the fresh water beneath the earth surface supplying the wells and springs; it is a major sources of drinking water and there is a growing concern over pollution by leaching of agricultural and industrial pollutants.

The scarcity of water resources is one of the main challenges for Jordan and a limiting factor for economic

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development especially for industry and agriculture. Jordan is considered among the poorest countries in the world in term of water resources.

The present study was focused on the assessment of the water quality of the springs in the Shoubak basin to determine the source of pollutants in the water samples, study the physical, chemical, and biological characteristics of Shoubak spring waters and characterize the suitability of springs for drinking and agricultural purposes.

1.1 Study area

The study area is located about 210 km from Amman in the southern part of Jordan, it is bounded by the coordinates latitude $30^{\circ} 31' N$ and longitude $35^{\circ} 32' E$ (Fig. 1).

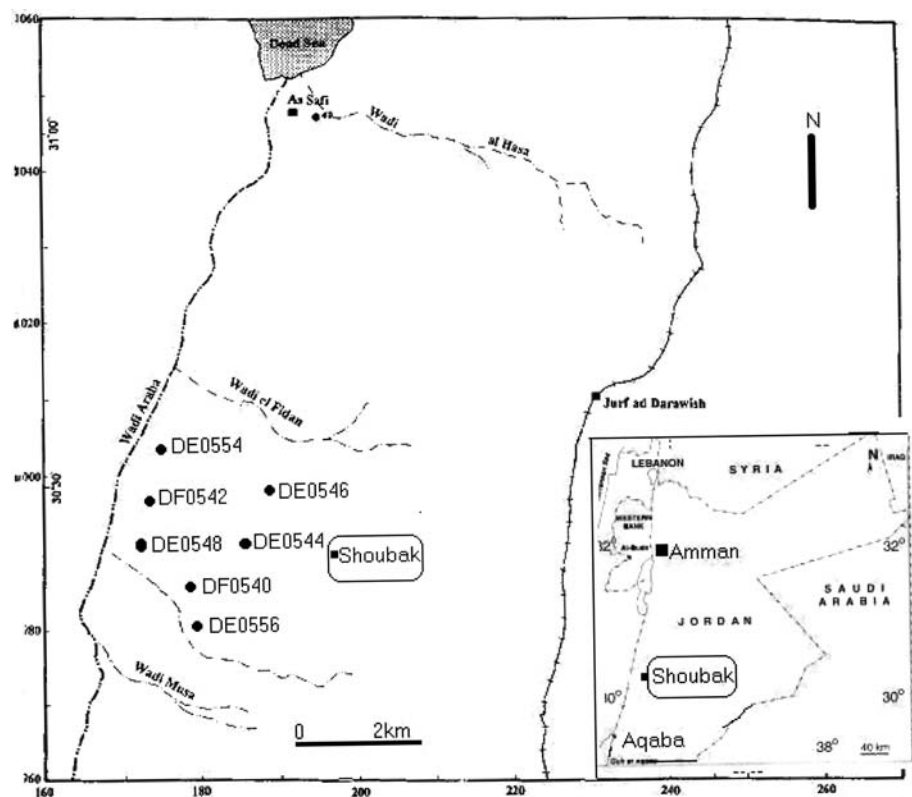
Shoubak lies on the edges of the mountainous desert of the Wadi Araba. There is a great variation in the nature of the topography in the area. The elevation varies from 1340 m above mean sea level in Shoubak area to maximum altitude of 1734 m above sea level at Jabel Al-Hisha, 6 km north of Wadi Musa. The study area in general is considered as a very arid to semiarid area, and is marked by sharp seasonal variation in both temperature and precipitation. The total rainfall for year investigated was about 321 mm/year (Table 1) (Department of Meteorology 2004).

Table 1 Total monthly rainfall and yearly of the Shoubak area during the rainy season 2004–2005 (mm)

Months	mm
October 2004	16.8
November 2004	12.5
December 2004	107.3
January 2005	98.8
February 2005	64.1
March 2005	9.1
April 2005	22.0
May 2005	0.2
Yearly	321.8

Winter in Jordan is the principle season of rainfall, the “water year” starts in late October and lasts until April. The average temperature is $20.3^{\circ}C$, with minimum values of $-1.0^{\circ}C$ in January and maximum of $33.5^{\circ}C$ in July (Department of Meteorology 2004). The maximum sunshine duration occurs in June with absolute values of 12.1 h/day, but in winter (December and January) the average minimum sunshine is only about 4.3 h/day. The average relative humidity varies from 73.6 to 44.4% in the winter months and from 38.1 to 57.2% in the summer season. The prevailing wind direction is from westerly to southwesterly. Water resources in Jordan mainly depend on

Fig. 1 Location map of the samples of springs



rainfall, which is highly variable. Meanwhile, population growth (around 3.5% per year) is creating a high demand for water (Salameh 1996). Pollution is caused by high population growth and the lack of sewer systems, which results to infiltration of wastewater into spring and groundwater (Al-Kharabsheh and Ta'any 2003; Salameh 1996). In the towns and villages in Jordan wastewater from septic tanks and cesspools also infiltrate ground water so exacerbating pollution problems from metals, salinity, ionic composition such as; nitrate, sulfate, ammonia, phosphate, and organic materials. Spring water in the study area is the major source for drinking water and irrigational activities. The average discharge of springs ranges from 0.2 m³ h⁻¹ for Jghaileyeh spring to 147.7 m³ h⁻¹ for Al-Ghweir spring (Table 2).

The surface water in the study area is composed of ephemeral wadis that drain their water during winter to feed the water springs. Approximately 89% of the total amount of the rainfall water evaporates into the atmosphere and the rest flows in wadis as flood flows and some enters the groundwater. The study area is subdivided into several subdrainage areas of the wadis, which issue from the eastern highlands. Some of these wadis are perennial and the others are intermittent depending on the intensity and duration of rainfall and local topography of the area. In times of extensive rainfall, runoff concentrates in the wadis and flows out to produce alluvial fans. Part of the runoff

reaches to Wadi Araba and the rest infiltrates into the wadis sediments and feeds the groundwater (Al-Khashman 2002). The ground water resources in the investigated area consist of 17 springs emerging from Upper Cretaceous strata.

1.2 Geology of study area

The geology of the study area is shown in Fig. 2. The lithological units are sedimentary rocks including cretaceous and tertiary formation, which are mainly 40–480 m thick. Those composed of limestone, marl, chert, marly limestone, and chalky limestones with chert intercalation are found in the investigated area (Bender 1974) (Fig. 3).

Structurally, the area are intensively faulted and folded as a result of various tectonic activities. The basin is affected by many major faults and fault zones, these faults with directions E–W, WNW–ESE, N–S, NNE, and NE–SW trending faults. Most of the fold in the basin are well seen in the upper cretaceous and tertiary carbonate rocks.

1.3 Hydrogeology

Ground water is the main water resource for the area and appears to originate from Cretaceous aquifer system. Upper

Table 2 The major springs with their coordinate, altitude and average discharge at Shoubak basin (Water Authority files 2003)

Spring name	Identification number	Coordinate		Discharge (m ³ h ⁻¹)	Altitude (m)	Aquifer type
		East	North			
Jghaileyeh	DE 0556	202.800	996.900	0.2	1300	A7-B2
El-A'Asi	DE 0558	203.800	993.600	4.2	1300	A7-B2
Shammakh	DF 0540	198.800	989.000	4.2	1320	A7-B2
El-Raghayeh	DE 0542	203.700	993.400	3.3	1265	A7-B2
Aqeel	DE 0544	205.300	993.700	10.7	1145	B3
Mugarayyeh	DE 0546	203.700	995.600	6.7	1250	A7-B2
Essider	DE 0548	204.200	996.300	11.4	1125	B3
Jahair	DF 0542	198.900	992.300	0.9	1500	A7-B2
Hawalah	DF 0548	198.000	988.200	4.2	1340	A7-B2
Jenaina	DF 0546	197.000	988.200	3.2	1330	A1-A6
Ara'ir	DF 0544	199.100	992.700	0.4	1470	A7-B2
Liwainat	DE 0554	203.500	996.800	0.9	1220	B3
Onsor	DE 0540	203.700	993.800	–	1315	A7-B2
Ifjeij (Fouqa)	DE 0550	208.000	993.700	3.8	1240	B4
Ifjeij (Tehta)	DE 0552	208.200	994.000	2.4	1180	B4
Khalid	DE 0586	209.300	10.500	4	1140	A7-B2
Zubeidiya	DE 0584	208.300	10.500	2.7	1210	A1-A6
Al-Dathneh	EA-23	201.000	2.770	40.4	680	K
Al-Ghweir	AE- 22	200.950	2.750	147.7	660	K

Fig. 2 Geological map of the study area (after Bender 1974)

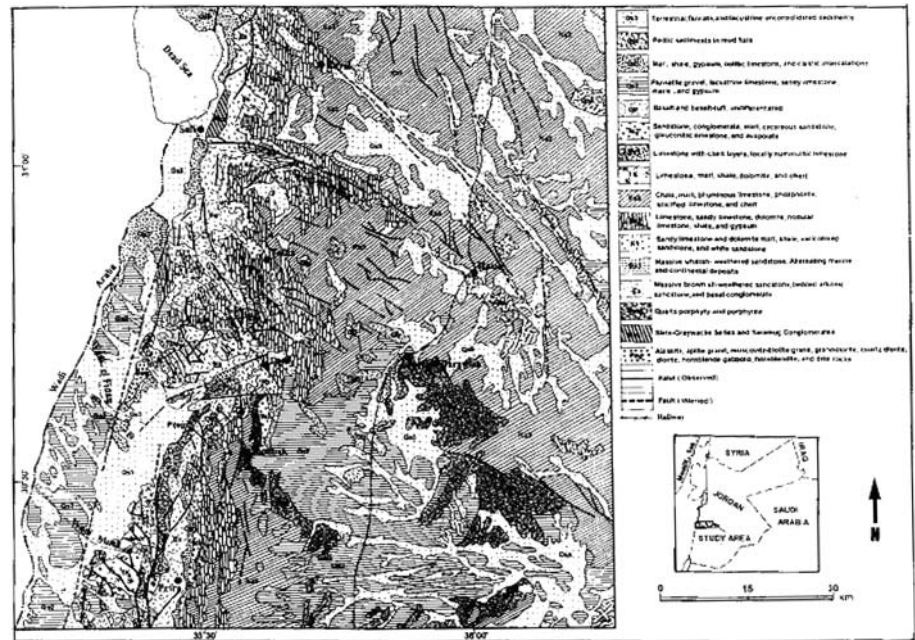
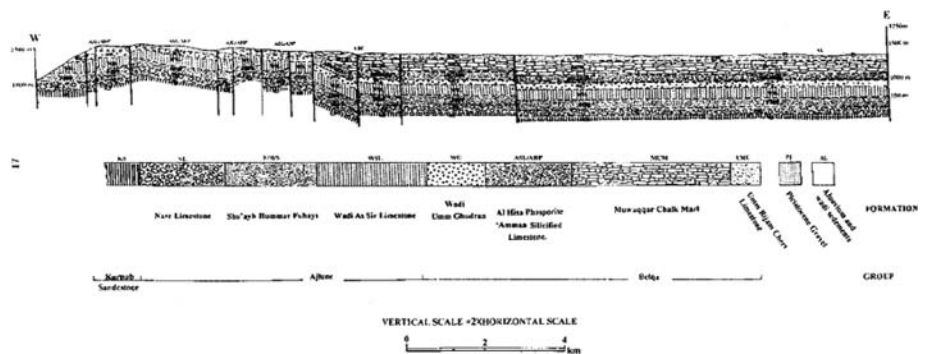


Fig. 3 The geological cross section of Shoubak area (after Bender 1974)



Cretaceous was the main aquifers in the area based on the potentiality of water bearing. Table 3 shows the Hydro-geological classification of rock type in study area and surrounding area. The A7-B2 aquifer is considered to be one of the most important groundwater reservoirs in the area as well as in Jordan. It has an excellent potentiality of water bearing and has a permeability of $1 \times 10 \text{ m}^3/\text{s}$ (JICA 1995). This aquifer consist of limestone, dolomite, limestone, marl, marly limestone, and chert. The direction of groundwater movement is from south–east to north–west. The Hummar and Na'ur formation (A4 and A1/2) are out cropping at the south part of the area, while they consist of crystalline dolomite limestone, gray limestone, and it is rich in micrite, wackstone, and chert nodules with thickness range from 112–220 m (Fig. 3). It is highly permeable when fractured and jointed forming a good aquifer in the study area (Macdonald 1965). The Kurnub sandstone aquifer (K), consist of massive, white and varicolored sandstone reaching with thickness ranges 450–550 m. The Kurnub group composed primarily of sandstones that take

place along the rift side of Tafila, Shoubak and Wadi Musa. The sequences jointed, well cemented to friable and highly permeable, hence possessing good aquifer properties. At the south part of the study area, Kurnub sandstone aquifer is confined with more than 600 m to reach the piezometric surface (Bender 1974; Sahawneh et al. 2000). The Kurnub Sandstone aquifer (K) crops out in the western part of the study area, which consist of massive white and varicolored sandstone reaching in total thickness about 300 m in Shoubak area (Macdonald 1965; Salameh and Udluft 1985) (Fig. 3).

2 Methodology

2.1 Sample collection and analysis

The Samples were collected in polyethylene bottles on the first day of each month commencing from May 2004 to May 2005. They were collected from seven representative

Table 3 Hydrogeological classification of rock types in the study area (Powell 1989)

Era	Period	Group	Formation	Symbol	General Lithology	Hydrogeological Classification	
Cenozoic	Quaternary		Alluvial deposits	JA	Sand, gravel, clay, lacustrine sediments, marl	Aquifer- aquiclude	
			Basalts	BS	Basalt, tuff, clay	Aquifer	
	Tertiary		Sirhan	S1–S2	Sandy marl, sandstone, clay, marl	Aquifer- aquitard	
			Basalts	B4-B1	Basalt, tuff, clay	Aquifer	
		Balqa	W. Shallaha	B5	Marl, clay, limestone, chert	Aquitard	
			Rijam		Chalky limestone with chert	Aquifer	
Mesozoic	Late Cretaceous		Muwaqquer	B3	Bituminous marl, chalky chert, shale	Aquitard	
			Amman	B2	Marly limestone, phosphates, chert	Aquifer	
			Umm Ghudran	B1	Marl, shale	Aquitard	
		Ajlun	Wadi Es Sir	A7	Marly limestone	Aquifer	
			Shueib	A5-A6	Argillaceous dolomite and limestone.	Aquitard	
			Hummar	A4	Limestone, dolomite limestone.		
			Fuheis	A3	Shale, sandstone		
	Early Cretaceous		Na'ur	A1-2	Dolomitized carbonate.		
			Kurnub	K	Sandstone	Aquifer	
	Jurassic		Huni		Sandy silt sand, shale	Aquiclude- aquifer	
	Triassic		Ma'in		Siltstone, mudstone	Aquiclude	
	Paleozoic	Cambrian-Silurian				Sandstone, dolomite limestone	Aquifer

springs distributed in the study area. Their biological, chemical, and physical parameters were analyzed according to the methods that suggested by Rand et al. (1995). Monthly samples were made to monitor changes caused by the seasonal hydrological cycle. During sampling, polyethylene sample bottles were rinsed in clear spring water several times and then filled to the top to minimize entrapment of air in water spring samples (Larsen et al. 2001). The samples destined to be used for metals analysis were reserved with nitric acid. On-site measured included, temperature, pH, electrical conductivity (EC), and dissolved oxygen (DO). All glassware and polyethylene bottles were soaked in 20% HNO₃ for 1 day and rinsed several times with deionized water before use. Conductivity measurements were made with 470 JENWAY conductivity meter with temperature compensation, and the pH values were measured in the field using 370 JENWAY pH-meter equipped with a combination glass electrode. Calibration was always carried out before measurement using standard buffer solutions of pH 4.00 and 7.00. Major anions (F⁻, Cl⁻, NO₃⁻, PO₄³⁻, and SO₄²⁻) were analyzed by 100 Dionex Ion Chromatography instruments and major cations (Ca²⁺, Mg²⁺, Na⁺, and K⁺) were measured by 800 Varian flame Atomic Absorption Spectrophotometer. The concentration of bicarbonate was determined by titration with 0.01 hydrochloric acid. Trace metals (Fe²⁺, Al³⁺, Mn²⁺, Cu²⁺, Cr²⁺, Ni²⁺, Zn²⁺, Pb²⁺, and Cd²⁺) were analyzed with Graphite Furnace using GTA 100 instruments. The standard solution of the anions, cations, and trace

metals as well as blank samples was prepared with different concentrations. After analysis the accuracy of these standards were within $\pm 7\%$. Total coliform count and faecal coliform count were determined using the multiple tube methods (APHA 1992; Shatanawi and Fayyad 1996). The total coliform numbers were determined in a Lauryl Tryptose broth and the tubes were incubated at 37°C for one day, but for the faecal coliform count, the FC broth was incubated at 44.5°C for one day.

3 Results and discussion

3.1 Hydrochemistry

About 84 water samples were collected from seven representative springs in Shoubak basin during the studying period, May 2004 to May 2005. Statistical summary of volume-weighted mean concentrations of physical and chemical parameters are presented in Table 4.

The ratio of total anions to that of cations ($(\sum \text{anions})/(\sum \text{cations})$) was an indicator for the completeness of measured parameters (Mouli et al 2005). The average equivalent sum of cations to that of anions ($(\sum \text{anions})/(\sum \text{cations})$) was 0.87 ± 0.21 . Also, for the set of samples considered in this study, linear regression of cation sum on anion sum gave value $R^2 = 0.91$ (Fig. 4), indicating that the quality of the data was good. The in-situ measured temperature for the water samples ranged between 13.1°C in

Table 4 The arithmetic mean, standard deviation and range of chemical and biological composition of spring water samples, n = 84 samples

Para	Jghaileyeh	Shammakh	Aqeel	Mugarayeh	Essidr	Jahair	Liwainat
T°C	19.1 ± 1.45 17.3–21.8	19.3 ± 1.26 17.6–21.3	17.8 ± 1.85 15.2–20.3	20.95 ± 3.03 16.3–24.6	18.85 ± 2.61 14.3–21.5	17.75 ± 2.2 13.7–20.4	16.7 ± 2.49 13.1–20.2
PH	7.59 ± 0.16 6.53–7.79	7.52 ± 0.10 7.36–7.66	7.60 ± 0.13 7.48–7.91	7.68 ± 0.19 7.31–7.96	7.76 ± 0.14 7.55–8.03	7.66 ± 0.14 7.47–7.95	7.63 ± 0.18 7.35–7.96
EC (µs/cm)	655 ± 59.95 521–690	432 ± 15.72 406–456	1195 ± 37.44 1150–1260	942.5 ± 56.18 860–1020	968 ± 63.81 950–1206	453 ± 52.56 415–580	1200 ± 57.33 1106–1300
DO (mg/l)	3.9 ± 1.36 1.69–5.8	6.6 ± 0.76 4.5–7.2	3.55 ± 1.36 1.4–5.6	4.00 ± 1.10 1.8–5.9	4.7 ± 0.69 3.8–5.8	5.5 ± 0.78 4.5–6.8	3.95 ± 1.41 1.6–5.4
TDS (mg/l)	419.2 ± 38.37 333.44–441.60	276.16 ± 10.0 259.84–291.84	764.8 ± 23.96 736–806.4	603.2 ± 35.96 550.4–652.8	619.52 ± 66.4 608–771.84	289.92 ± 32.82 265.6–371.2	768 ± 36.71 707.84–832
Ca ²⁺ (meq/l)	3.22 ± 0.18 2.9–3.42	3.0 ± 0.21 2.81–3.36	7.99 ± 0.12 7.7–8.12	7.81 ± 0.14 7.6–8.03	7.38 ± 0.26 7.21–8.1	4.72 ± 0.41 3.87–5.3	7.38 ± 0.15 7.1–7.56
Mg ²⁺ (meq/l)	2.36 ± 0.12 2.22–2.61	2.08 ± 0.25 1.65–2.38	4.11 ± 0.14 3.9–4.31	4.69 ± 0.23 4.41–5.1	4.44 ± 0.20 4.3–4.95	2.96 ± 0.4 1.9–3.3	3.9 ± 0.26 3.5–4.31
Na ⁺ (meq/l)	1.23 ± 0.23 0.9–1.52	1.03 ± 0.26 0.52–1.36	1.29 ± 0.21 0.95–1.53	2.86 ± 0.22 2.5–3.1	2.72 ± 0.24 2.5–3.36	1.26 ± 0.29 0.7–1.67	2.56 ± 0.20 2.3–2.96
K ⁺ (meq/l)	0.18 ± 0.09 0.07–0.33	0.14 ± 0.08 0.05–0.28	0.21 ± 0.11 0.09–0.4	0.3 ± 0.05 0.18–0.37	0.17 ± 0.09 0.09–0.40	0.18 ± 0.06 0.09–0.29	0.34 ± 0.23 0.09–0.76
Cl ⁻ (meq/l)	1.55 ± 0.20 1.33–1.94	1.46 ± 0.17 1.19–1.67	2.87 ± 8.21 2.65–3.01	4.68 ± 0.11 4.5–4.81	4.52 ± 0.14 4.38–4.83	2.98 ± 0.41 2.21–3.5	4.2 ± 0.19 3.96–4.52
SO ₄ ²⁻ (meq/l)	1.5 ± 0.21 1.3–1.92	1.48 ± 2.36 0.59–1.61	4.91 ± 8.23 4.46–5.3	3.7 ± 0.07 3.55–3.81	2.99 ± 0.20 2.85–3.49	1.63 ± 0.33 1.1–2.3	2.94 ± 0.24 2.55–3.3
HCO ₃ ⁻ (meq/l)	2.86 ± 0.18 2.59–3.14	2.81 ± 8.23 2.51–3.08	4.33 ± 8.33 3.97–4.6	4.66 ± 0.20 4.47–4.96	4.52 ± 0.23 4.36–5.03	2.94 ± 0.23 2.34–3.2	4.35 ± 0.20 4.2–4.8
NO ₃ ⁻ (meq/l)	1.05 ± 0.17 0.7–1.21	0.71 ± 2.10 0.52–0.91	1.18 ± 3.23 0.91–1.31	2.46 ± 0.22 2.16–2.75	2.51 ± 0.18 2.41–2.95	1.29 ± 0.28 0.88–1.83	2.48 ± 0.22 2.16–2.9
PO ₄ ³⁻ (meq/l)	0.03 ± 0.02 0.03–0.08	0.02 ± 0.02 0.003–0.06	0.09 ± 0.08 0.002–0.08	0.18 ± 0.16 0.09–0.20	0.11 ± 0.14 0.009–0.06	0.05 ± 0.02 0.009–0.02	0.22 ± 0.11 0.05–0.42
F ⁻ (meq/l)	0.014 ± 0.01 0.010–0.009	0.009 ± 0.009 0.009–0.001	0.018 ± 0.014 0.009–0.018	0.011 ± 0.08 0.001–0.012	0.015 ± 0.011 0.007–0.03	0.013 ± 0.0 0.014–0.04	0.02 ± 0.02 0.01–0.05
Total coliform (MPN 100 ml ⁻¹)	1040.67 ± 23 1023–1090	141.21 ± 212 105.3–155.3	1509.6 ± 452 1250–5321.3	3264.2 ± 1398.2 1850.3–3852.1	1750.12 ± 1210.39 855.36–2015.3	230.41 ± 212.56 150.2–355.4	3715.12 ± 2101.23 1501–4512.3
Faecal coliform (MPN 100 ml ⁻¹)	13.85 ± 12.48 26.04–10.30	3.21 ± 9.23 1.22–3.8	220.18 ± 61.2 118.23–450.12	2950.50 ± 422.21 1402–3156.2	308.17 ± 1047.91 154.23–750.55	8.86 ± 12.9 5.53–12.35	1809.67 ± 1041.21 1400.3–3543.2

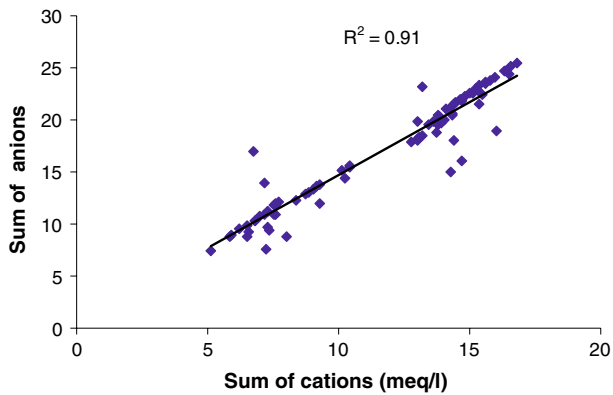


Fig. 4 Sum of cations against sum of anions (meq/l) of spring water analysis

Liwainat spring in wet season and 24.6°C in Mugarayyeh spring in dry season, with a median value of 18.6°C ± 2.49. The variation in the recorded temperature for all the springs in the study area were mainly a result of the depth at which the springs emerged (Al-Khashman 2002). The pH in all sampling sites was in the range 6.53 in Jghaileyeh spring to 8.03 in Essider spring, with a median value of 7.62 ± 0.17. The variations in the measured pH values of different springs were mainly caused by increases of bicarbonate concentration in the water aquifers. Although the median values of pH in

Table 5 Jordanian Standards and WHO guidelines for drinking water quality

Parameter	Jordanian standards (2003)	WHO standards (2004)
Temperature (°C)	12–25	12–25
pH	6.5–9.0	6.5–8.5
EC (mSm ⁻¹)	–	400
Na ⁺ (mg/l)	200–400	200
Ca ²⁺ (mg/l)	75–200	100
Mg ²⁺ (mg/l)	50–150	50
K ⁺ (mg/l)	10–50	20
HCO ₃ ⁻ (mg/l)	100–500	125–350
Cl ⁻ (mg/l)	200–500	250
SO ₄ ²⁻ (mg/l)	200–500	250
NO ₃ ⁻ (mg/l)	70	50
TDS (mg/l)	500–1500	500–1000
TH (mg/l)	500	500
Fe ²⁺ (mg/l)	0.3–1.0	0.3
Mn ²⁺ (mg/l)	0.1–0.2	0.1–0.5
Zn ²⁺ (mg/l)	5–15	0.01–3
Al ³⁺ (mg/l)	0.2–0.3	0.2
Pb ²⁺ (mg/l)	0.05	0.01
Cu ²⁺ (mg/l)	–	2
Cd ²⁺ (mg/l)	–	0.003

spring water samples were rather similar to the proposed Jordanian and, WHO drinking water standards (Table 5).

The electrical conductivity (EC) of the spring water ranged from 406 μs/cm in Shammakh spring to 1300 μs/cm in Liwainat spring with a median value of 937 ± 310.25 μs/cm at 25°C. However, the high conductivity of the water samples in Shoubak basin corresponding to the highest of dominant ions, which results from ion exchange and solubility of rocks in aquifer (Virikutyte and Sillanpää 2005; Zacheous and Martikainen 1997).

Total Dissolved Solid (TDS) values in spring’s water varied from 259.84 mg/l in El-Shammakh spring to 832 mg/l in Liwainat spring (Fig. 5). In general, all the TDS values of the spring water fall within the permissible limit of Jordanian Standards for drinking water (2003). In general there is an increasing tendency in the TDS values in dry seasons compared with wet seasons except for April TDS is higher than in June. Calcium is widely distributed in the bedrocks and soil of the study area.

The geological sources of calcium variable can be minerals such as anorthite, aragonite, gypsum as well as calcite and dolomite which the most abundant rock minerals as in the B2/A7 aquifer in the investigated area. Calcium was mainly controlled by dissolution of silicate minerals and by reactions in the carbonate system (Magaritz et al 1989). The calcium content of the spring water varied between 2.8 meq/l in El-Shammakh spring and 8.12 meq/l in Aqeel spring in the wet season, with a median value of 7.29 ± 2.07 meq/l. The higher value of calcium in the dry season in Aqeel spring was due to the release of calcium from the sedimentary carbonate rocks and soils to the aquifer (Fig. 6). The median calcium concentrations in wet seasons were lower than in a dry season, which is a result of the rapid movement of rainwater, less dissolution of soil minerals and rocks. The concentration of sodium in the water samples

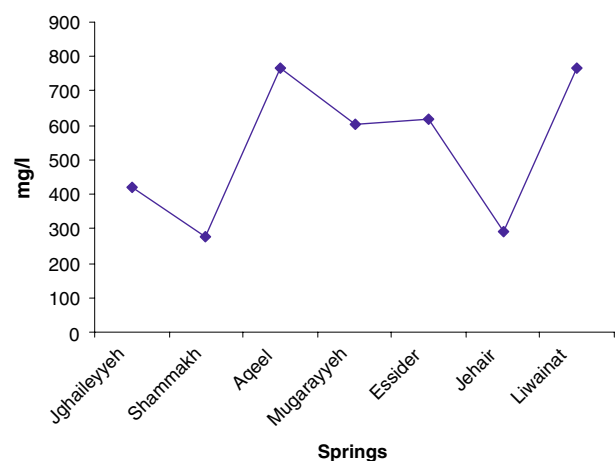


Fig. 5 Median values of Total Dissolved Solid (TDS) for the spring water

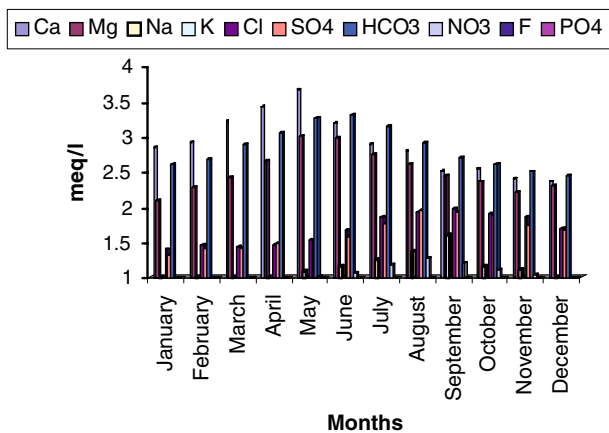


Fig. 6 Monthly mean values of ionic concentrations in water samples

ranged from 0.52 meq/l in El-Shammakh spring to 3.36 meq/l in Essider spring, with a median value of 1.51 ± 0.81 meq/l (Table 5). The high concentration of sodium in water samples in the summer season result from wastewater infiltration and uses of fertilizers in agricultural activities around Essider, Jghaileyeh, Aqeel, and Mugarayyeh springs. The lowest value in sodium concentrations from dry to wet seasons reflects the dilution of groundwater by rainwater. Sodium ion makes a relatively medium contribution compared to calcium and magnesium. The median $\text{Na}^+ : \text{Cl}^-$ ratio were found <1 for the springs, while the lower ratio of NaCl in spring water samples is caused by reaction with clay minerals exchanging sodium for calcium and magnesium ions near the outlets of the springs (Mercado 1985; Al-Khashman 2007). The whole aquifer consists of alternate limestone and marl layers. The clay in marl most probably is the exchange medium.

The strong correlation was noticed between sodium and chloride of water ($R^2 = 0.87$) suggesting that the main source for NaCl should be wastewater infiltration and another source for chloride may be KCl from fertilizers were used in agricultural activities in the investigated area. Anions such as chloride, sulfate, and nitrate were the major inorganic components deteriorating the quality of groundwater as drinking water. The spring water samples from five sites in Shoubak basin were shown in nitrate contents greater than the Jordanian Standards for drinking water (2003) guideline (70 mg/l as NO_3^-) accepted for drinking water (Table 5). Especially, samples in the El-Mugarayyeh, Essider, and Liwainat were highly contaminated by NO_3^- (above 100 mg/l). Nitrate likely comes from pollution sources such as atmospheric fallout, sanitation facilities, and domestic effluents (Ritzi et al. 1993; Jeong 2001). The increasing number of scattered buildings and the high population growth increases the pollution of water resources in the study area. The springs were directly influenced by pollution sources through the fissures and fractures that associated with the carbonate aquifers. The sulfate, nitrate, and chloride contents of the

springs have increased sharply during the study period, indicating that pollution of springs in the study area will accelerate sharply in the future and water resources will not be suitable for uses.

The springs in the study area that are located beside the residential areas have been affected more than other springs. These springs are directly recharged with polluted water through fissures and fractures of carbonate aquifers. High concentrations of nitrate in water samples found far way from the cesspools in town downs were mainly caused by fertilizers, manure, and plant decomposition such as at Mugarayyeh, Essider, Liwainat, and Aqeel (Fig. 7). The sulfate concentration in the spring water varied between 0.59 meq/l in Shammakh spring and 5.3 meq/l in Aqeel spring, with a median value of 2.88 meq/l. The high concentration of sulfate in this spring was mainly attributed to anthropogenic activities around the springs. In the collected spring water samples from different aquifers, the highest concentration of bicarbonate was found in Essider, Aqeel, and Liwainat springs.

Chloride concentrations ranged from 1.46 meq/l in El-Shammakh spring to 4.68 meq/l in Mugarayyeh spring (Fig. 7). However, high value of chloride in the water samples likely originated from pollution sources such as; domestic effluents, fertilizers, septic tanks, and from natural sources such as rainfall, dissolution of fluid inclusions, and Cl^- bearing minerals (Ritz et al. 1993; Jeong 2001).

Bicarbonate values in water samples ranged from 2.8 meq/l in El-Shammakh spring to 4.66 meq/l in Mugarayyeh spring. The increase of bicarbonate in the wet season is attributed to the dissolution of carbonate rocks and leaching to the saturated zone in the different aquifers (Dojlido and Best 1993). The high correlation between bicarbonate and sulfate was ($R^2 = 0.82$), indicates the dissolution of carbonate rock which contain traces of

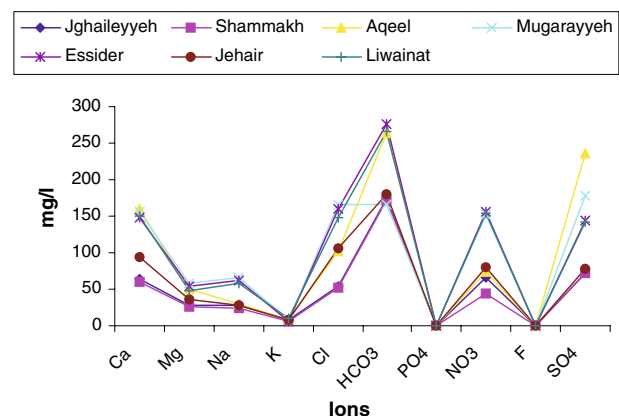


Fig. 7 Median value of ionic compositions of spring water samples by location

laminated fibrous and nodular gypsum and mineral leaching to the saturated zone in the various aquifers.

The suitability of water samples for domestic purposes was determined by comparing the chemical constituents with Jordanian Standards for drinking water (2003), and according to Sawyer and McCarty (1967) it is concluded that most of the spring water samples can be considered as a very hard water.

Groundwater exchanges matter with the various minerals and gases within the aquifer resulting in a dissolution or precipitation of minerals. Equilibrium calculations are most commonly used to assess whether or not water is in equilibrium with respect to one or more minerals (Subyani 2005). The saturation indices of minerals in the spring water can be expressed by the saturation index (SI). When $SI < 1$, the minerals dissolve, on the other hand, the minerals precipitated when $SI > 1$ (Fetter 1988; Subyani 2005). The statistical analysis of saturation indices of spring water samples are listed in Table 6. All spring water samples had positive calcite and dolomite indices, indicating that the waters were oversaturated with respect to calcite and dolomite. The water chemistry of cation and anion proportions in groundwater samples are shown on the trilinear diagram of Piper (1953) and then interpreted depending on the classification given by Langguth 1966 (Fig. 8). The water chemistry of springs was classified to the alkaline earth waters type with prevailing bicarbonate and alkaline earth waters with prevailing bicarbonate chloride. The chemistry of this water shows the following ionic ratio: $Ca^{2+} > Mg^{2+} > Na^+ > K^+$ and $HCO_3^- > Cl^- > SO_4^{2-} > NO_3^-$. Water chemistry originate from dissolution of carbonate rocks. However, the water was generally classified as Ca-HCO₃ water with low salinity.

3.2 Biological characteristics

Total coliform count (TC) and faecal coliform (FC) for this study were presented in Table 4.

Biological characteristics of water samples show high value of TC and FC in water samples from Jghaileyeh,

Aqeel, Mugarayyeh, Essider, and Liwainat were highly contaminated by TC and FC and exceed WHO guideline (1000 MPN/100 ml⁻¹) (WHO 2004). The microbiological parameters varied from summer to winter. In summer, faecal coliform counts of samples analyzed were higher than 1000 MPN/100 ml⁻¹ due to high temperature and climatic conditions. Generally, the springs were polluted and the value of total coliform and faecal coliform were not decreasing during the rainy season, because the water feed was negligible in relation to the wastewater feed from cesspools and septic tanks (Al-Kharabsheh and Ta'any 2003).

3.3 Assessment of contribution by factor analysis

Factor analysis of chemical data was used to quality the contribution of natural chemical weathering and anthropogenic inputs to the chemical composition of springs in the Shoubak basin. The results of factor analysis based on the four most significant factors indicate that these factors explain about 83% of the total variance in the water samples (Table 7). The first factor component, accounting for 48.9% of the total variance. This factor has high loadings on the elements Fe²⁺, Mn²⁺, Cr³⁺, Ni²⁺, Zn²⁺, Pb²⁺, and Cd²⁺ and ions Ca²⁺, Mg²⁺, and SO₄²⁻.

The high loadings of these elements indicate the influence of local anthropogenic activities such as agricultural activities and wastewater feed the springs through the fissures and fractures. On the other hand, calcium and magnesium are definitely attributed to carbonate dissolution. The second factor has high loadings of ions Na⁺, K⁺, Cl⁻, HCO₃⁻ and elements Al³⁺ and Cu²⁺, and explains about 13.2% of the total variance. The high loadings of Al³⁺ and Cu²⁺ indicates the influence of natural source associated with soil and crustal combustion “soil leaching” processes (Simeonov et al. 2003). Meanwhile, the source of sodium, potassium, and chloride are fertilizers and wastewater sources in the investigated area. The third factor shows high loadings for pH, EC, and DO, accounting for 8.9% of the total variance, while this factor represents the

Table 6 The arithmetic mean, standard deviation of saturated indices of spring water samples

Spring name	SI _{calcite}	SI _{dolomite}	SI _{gypsum}	SI _{anhydrate}
Jghaileyeh	0.28 ± 0.23	1.27 ± 1.60	-2.34 ± 1.11	-2.85 ± 1.15
Shammakh	0.15 ± 0.18	1.37 ± 0.95	-2.24 ± 0.31	-2.59 ± 1.08
Aqeel	0.56 ± 0.26	1.57 ± 1.65	-1.99 ± 0.95	-2.44 ± 1.03
Mugarayyeh	0.33 ± 0.31	1.10 ± 1.22	-2.05 ± 1.03	-2.37 ± 0.99
Essider	0.69 ± 0.27	1.07 ± 0.96	-2.02 ± 1.01	-2.51 ± 0.91
Jahair	0.22 ± 0.21	1.20 ± 1.10	-1.95 ± 0.99	-2.24 ± 0.94
Liwainat	0.37 ± 0.29	1.94 ± 1.27	-1.33 ± 0.88	-2.51 ± 1.05

Fig. 8 Piper diagram of spring waters (values % meq/l)

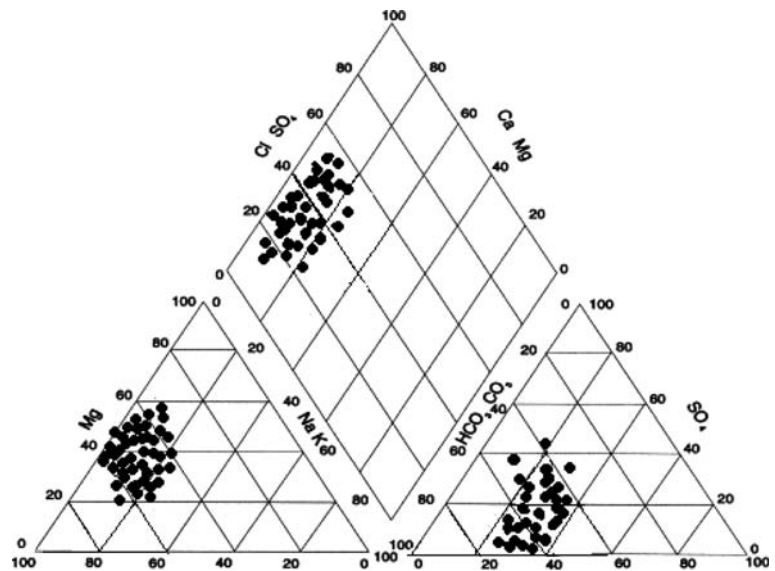


Table 7 Varimax rotated factor matrix and communalities for the chemical data set^a

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Communalities
pH	0.23	0.29	0.63	-0.16	0.78
EC	0.13	-0.33	0.89	-	0.92
DO	0.14	0.33	0.86	-0.17	0.92
Ca ²⁺	0.82	0.41	0.12	-0.22	0.98
Mg ²⁺	0.91	0.23	0.19	-0.13	0.94
Na ⁺	0.32	0.70	0.21	-0.44	0.84
K ⁺	0.2	0.72	0.33	-	0.57
Cl ⁻	0.55	0.75	-	-0.23	0.89
SO ₄ ²⁻	0.76	0.12	0.17	-	0.91
HCO ₃ ⁻	0.5	0.79	-0.23	-0.22	0.95
NO ₃ ⁻	0.24	0.37	-0.18	0.69	0.91
PO ₄ ³⁻	0.17	0.14	0.15	0.70	0.83
F ⁻	0.15	0.19	0.21	0.74	0.77
Fe ²⁺	0.78	0.31	0.14	0.15	0.73
Al ³⁺	0.55	0.65	0.18	-0.19	0.78
Mn ²⁺	0.72	-0.29	-0.21	0.17	0.62
Cu ²⁺	0.24	0.78	0.1	-	0.9
Cr ³⁺	0.70	-0.14	0.48	-0.12	0.66
Ni ²⁺	0.71	-0.54	0.26	-0.2	0.62
Zn ²⁺	0.65	0.46	0.44	0.21	0.83
Pb ²⁺	0.83	-0.25	0.23	-0.17	0.85
Cd ²⁺	0.67	0.37	0.41	-0.15	0.78
% of total variance	48.92	13.24	8.96	5.64	

^a Significant factor loadings are bold faced

“physicochemical” source of the variability, but the fourth factor was correlated with NO₃⁻, PO₄³⁻ and F⁻. This factor resulted by agricultural activities (fertilizers, pesticides,

and manure) that used in farms around the springs, and wastewater resulted by cesspools in town downs beside the spring sites.

3.4 Trace metals

Trace metals may present in natural surface and groundwater, while the sources of these metals are associated with either, natural processes and human activities. Chemical weathering and soil leaching are the two important natural sources contribution the increasing of trace metals concentration in water (Drever 1988). Many factors that affect the release of trace metals from primary materials and soil, and consequently their stability in water such as; pH, adsorption characteristics, hydration, and co-precipitation (Drever 1988; Fetter 1988). The statistical analysis of metal contents in the study area was given in Table 8.

Most of the water samples showed low metallic content which could be attributed to the high pH value larger than seven enhancing the deposition of these metals or related their dissolution from the rock matrix (Al-Khashman 2002; Al-Awadi et al. 2003). The concentration of iron in water samples from production springs maximum 193 µg/l for sample from Mugarayyeh spring. The iron content in the springs was much below the WHO set limit for drinking water. The iron concentration is generally low in spring. In general there is a strong correlation between oxygen and iron. Iron is mobilized under anoxic conditions. The highest value of iron was recorded in Mugarayyeh spring which contains 208 µg/l (Table 8). On the other hand, the highest value of lead was measured in Essider spring, but the lowest value was recorded in Shammakh spring (Fig. 9). Most of the springs in the

Table 8 The arithmetic mean, standard deviation, and concentration range of trace metals composition of spring water samples, n = 84 samples

Para.	Jghaileyeyeh	Shammakh	Aqeel	Mugarayyeh	Essider	Jahair	Liwainat
Fe ²⁺ (µg/l)	112.5 ± 6.06 85–128	66.0 ± 10.14 51–85	141.5 ± 23.12 104–170	193.0 ± 9.52 179–208	95.0 ± 12.28 87–125	82.5 ± 9.43 66–95	191.2 ± 9.3 116–207
Al ³⁺ (µg/l)	88.0 ± 8.42 65–142	62.5 ± 11.47 45–80	103.0 ± 8.31 106–157	120.0 ± 9.66 166–195	50.0 ± 8.09 40–66	83.0 ± 6.73 71–91	130.0 ± 9.2 125–130
Mn ²⁺ (µg/l)	9.0 ± 2.02 6–12	3.5 ± 2.4 1–8	13.0 ± 2.45 8–16	20.5 ± 5.61 11–28	12.5 ± 4.35 4–18	13.5 ± 3.62 8–19	16.0 ± 2.11 12–19
Cu ²⁺ (µg/l)	13.5 ± 3.38 8–20	8.0 ± 4.62 2–15	23.5 ± 4.48 15–29	9.5 ± 3.01 4–13	4.5 ± 2.1 1–8	2.5 ± 1.73 1–6	12.5 ± 2.13 10–16
Cr ³⁺ (µg/l)	2.0 ± 1.31 1–5	2.0 ± 0.94 1–4	3.0 ± 2.41 1–9	3.9 ± 2.61 1–9	2.88 ± 1.55 2–10	2.1 ± 0.99 2–9	5.3 ± 2.28 4–16
Ni ²⁺ (µg/l)	10.5 ± 4.11 2–16	7.5 ± 4.95 4–14	16.5 ± 2.49 12–20	18 ± 1.85 15–22	18.5 ± 2.91 14–23	12 ± 3.70 8–16	17.5 ± 3.65 12–24
Zn ²⁺ (µg/l)	24.0 ± 2.9 18–27	13.5 ± 4.45 5–18	22.5 ± 5.90 11–29	24.5 ± 7.37 10–33	19.0 ± 6.23 11–29	17.5 ± 5.63 10–27	25.5 ± 6.24 11–34
Pb ²⁺ (µg/l)	17.5 ± 4.97 11–28	18.0 ± 4.75 10–26	34.5 ± 5.65 22–42	42.0 ± 7.5 28–51	41.5 ± 11.29 26–60	38.0 ± 6.15 28–48	47.0 ± 4.53 39–54
Cd ²⁺ (µg/l)	11.0 ± 3.6 4–16	5.5 ± 3.04 2–11	9.6 ± 2.45 6–16	11.0 ± 5.75 2–19	10.0 ± 4.61 3–17	6.50 ± 3.12 3–15	13.5 ± 2.33 10–20

investigated area contain values of lead below the tolerance limits (0.05 mg/l) from Jordanian standard for drinking water 2003. The median value of Mn in the springs emerged from different locations ranged from 3.5 µg/l in Shammakh spring to 21 µg/l in Mugarayyeh spring. The highest value of Mn was found in Mugarayyeh spring which reached to 21 µg/l due to municipal waste and septic tanks that are responsible for the concentration of Mn in the study area, which considered as below than the permissible limits for drinking water quality. Zinc concentration in the studied spring ranged from 13 µg/l in Shammakh spring to 26 µg/l in Liwainat spring, thus all the studied springs water do not exceed the recommended limit (Jordanian standard 2003). Other trace metals showed lower concentration in the water samples, and these metals lower than the recommended limit for drinking water.

3.5 Environmental concern and pollution sources

The most important environmental problem in the investigated area is uncontrolled disposal of untreated wastewater. Wastewater is considered to be major source of pollution that affects groundwater quality if disposed untreated to the environment. Domestic wastewater is general in houses holds, commercial and public institutions by human being. Cesspools are considered to be the most widespread wastewater disposal methods in Shoubak area. Cesspools are designed to serve single or multiple apartment buildings and most of cesspits are built without concrete basement. The

springs are directly invaded by pollution sources through the fractures associated with carbonate aquifers. The springs that are located near residential areas have been affected more than other springs distributed in the investigated area. Most of springs are directly recharged with wastewater through the joints, fissures, and fractures associated with carbonate aquifers. The most common agricultural practices that contribute to high degree in groundwater pollution are the uncontrolled use of pesticides and fertilizers without any restrictions and monitoring farmers for the agricultural pest control in the investigated area.

4 Conclusion

Investigation of physical, chemical, and biological composition of spring water was carried out over a one-year

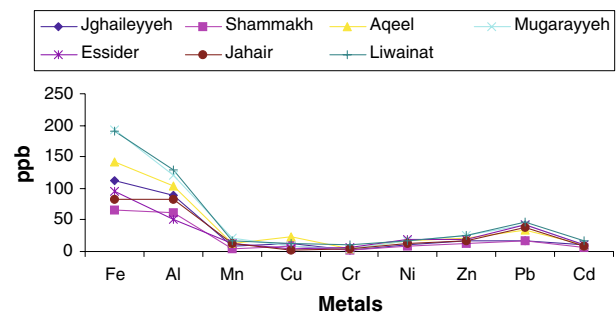
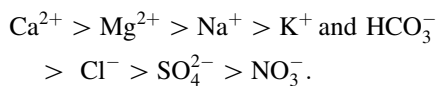


Fig. 9 Median value of metal concentrations in spring water samples by location

period at Shoubak basin, which represents the first contribution in the basin to knowledge of water quality. Results suggest that the spring water samples were typically alkaline. The chloride, sodium, calcium, bicarbonate, and magnesium were the major source of salinity in the water, while the ion values increased compared with precipitation water due to dissolution of carbonate rocks and ion exchange processes including minerals. The result of this study indicates that the inorganic constituents of water were influenced by natural sources and anthropogenic sources and indicate that some of the springs were highly polluted with nitrate and sulfate from surface pollution. Such as; agricultural activities, wastewater recharge from cesspools and septic tanks. The springs that were located near residential areas have been affected larger than other springs. These springs were directly fed with wastewater through fractures, joints, faults, and fissures of associated with carbonate aquifers. Biologically, the springs were polluted and concentration of total coliform and faecal coliform were growth and not decreasing during rainy season. The water of springs was classified into two groups: alkaline earth waters with prevailing bicarbonate and alkaline earth waters with prevailing chloride. The chemistry of this water shows the following ionic ratio:



Trace metals content in the spring water samples were low due to slightly alkaline water. The use of factor analysis facilities the interpretation of the water characterization highlighting the influence of anthropogenic activities and natural sources in the studied area. This study has shown that the trace metals quality of waters in Shoubak basin was generally good, most of the elements satisfying the Jordanian and WHO regulations for drinking waters.

To the best of my knowledge, this is the first detailed study of water quality in Shoubak area southern part of Jordan. It should provide a good baseline for setting standards for water quality in country. Based on the results of this study the following recommendations are appropriate:

1. This study recommended that the groundwater in the area required monitoring and protection from pollutants, whether that originating from municipal refuse and wastewater or from chemical fertilizers used in agricultural activities.
2. Connect the houses within the study area with present sewage system to protection groundwater for any source of pollution.
3. In future, Further study is also warranted to identify the physical, chemical, and biological parameters that are important to monitoring spring and well water

quality and further research is needed to characterize the organic compounds in spring water quality.

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