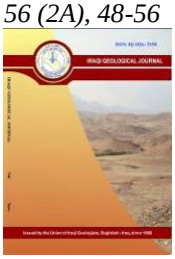
Iraqi Geological Journal

Journal homepage: https://www.igj-iraq.org



Springs Water Quality Assessment for Drinking Purposes: A Case Study of Bsaira, Jordan

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Received:
18 September 2022

Accepted:
10 March 2023

Published:
31 July 2023

Abstract

Water scarcity is one of the biggest challenges to Jordan. Jordan is considered one of the poorest countries in the world in terms of freshwater availability. The protection of freshwater springs from pollution is among the possible solutions that can help in mitigating the water scarcity problem. In this study, the quality and quantity of water flowing from three springs namely Um Sarab, Dana, and Gharandl within Bsaira area that is located in Tafilah governorate in Jordan were evaluated as potential drinking water sources. During the spring period (March to June 2021), several water samples from the springs were collected and tested for biological, physical, and chemical parameters. Spring water samples were tested for (Ni, Co, Cr, Cu, Fe, Pb, Mn, Zn, Na^+, K^+, Mg^{2+}, Ca^{2+}), pH, total dissolved solids, chemical oxygen demand, turbidity, total solids, total coliforms, and E-coli. Results indicated that all the physical and chemical parameters of water in the three springs are within the acceptable standard limits according to Jordanian standards for drinking water. However, the biological parameters (i.e. total coliforms and E-coli) exceeded the permissible limits, and this is more significant in Gharandl spring. The field investigation of the study area showed that the main sources of pollution are the presence of many septic tanks and agricultural activities in the surrounding areas of the springs. Therefore, applying Jordanian regulations for the protection of groundwater resources can significantly improve the quality of water in these springs. The total quantity of water from these springs exceeds 1300 m^3/day which is considered a significant source of drinking water after local treatment and disinfection.

Keywords: Spring water; Allowable limits; Heavy metals; Biological indicators; E-coli

1. Introduction

The need for safe drinking water sources is growing around the world due to the rapidly increasing pollution of water bodies as a result of the rapid growth of the world's population and anthropogenic activities. About 29 percent of the global population lack access to safely controlled drinking water, and one out of every three people living in rural areas does not use such water (WHO & UNICEF, 2017).

Jordan is one of the world's most water-scarce nations. In addition to the high rate of population growth, the influx of refugees escaping regional conflicts added more pressure on the already limited

DOI: 10.46717/igj.56.2A.4ms-2023-7-13

water sources. Moreover, climate change which results in changing rainfall patterns threatens to worsen the case (USAID, 2021). The climate change impacts indications showed that rainfall is the main indicator that is heavily affected especially in South Jordan areas (Matouq et al. 2013). Therefore, in Jordan, several works and studies have been directed toward finding alternative water sources to overcome water scarcity in the country. Among these alternatives is the reuse of greywater, and treated domestic and industrial wastewater. In Jordan About 13% of the treated domestic wastewater is being reused mainly for irrigation, meanwhile, the industrial wastewater consumption is growing and expected to reach 10 MCM/year (El-Hasan, 2017; Al-Mubaidin et al., 2022; Al-Hamaiedeh and Bino, 2010; Al-Hamaiedeh, 2010). The potential agricultural reuse of about 4 MCM of industrial wastewater produced from the wash of phosphate ore in the central Jordan phosphate mines (Al-Abyad and Al-Hisa) has been studied (Jireis et al. 2004.; El-Hasan, 2006).

Spring water is considered a valuable source of drinking water in many parts of the world. Climate change, specifically the reduction in rainfall besides human activities such as agriculture and urbanization is believed to be responsible for the reduction of springs discharge (Li & Wu, 2019). Moreover, springs are rapidly disappearing around the world due to the lack of proper management and conservation, especially in arid areas (Glazier, 2009). One of Jordan's main water resource concerns is the pollution of groundwater from both point and non-point sources. About 26 karst springs emerging from the Umm Rijam aquifer and three wells tapping the Amman - Wadi As-Sir aquifer were examined for NO3 concentrations by many researchers. The study brought attention to the issue of water quality deterioration and the urgent need to protect and manage water quality (Obeidat et al., 2008). The major threat to spring water in Tafila and Al-Karak provinces is the large use of septic tanks due to the absence of sewerage systems (Jiries et al. 2010). A similar result was highlighted by (Manasrah et al. 2010), who found that traces of pollution in Mujieb dam sediments is originated from Al-Lajoun septic tanks disposal site.

Batayneh (2011) studied the geochemistry of Yarmouk Basin in the north of Jordan and explored water quality in the major springs in the basin to verify their suitability for drinking purposes and irrigation. Results showed that the water quality of major springs in the Yarmouk Basin was suitable to be used for drinking and irrigation purposes. Al-Kazwini and Hasan (2003) measured radon concentration in Jordanian drinking water and hot springs. They found that Jordanian drinking water is healthy in terms of radon concentration except of a few isolated local drinking water wells. Ibrahim (2019), studied the groundwater quality in Jordan using the water quality index. Samples from 16 springs in different locations within the study area were collected for one year from 2015 to 2016. The results of the classification according to the quality index indicated that among 16 springs there were three springs classified as (excellent water for drinking purposes), nine springs were classified as (good water), one was classified as (poor water), two were classified as (very poor) and only one was classified as not suitable for drinking.

The total water consumption in Jordan in the year 2019 amounted to about 1,104.86 MCM, with an increase of about 28 MCM compared to 2018 (MWI, 2020). Domestic, agricultural, and industrial uses accounted for 45%, 50.7%, and 3.3% of the total consumption, respectively. Springs in Jordan contribute 36.85 MCM /year of water (MWI, 2020). The existing untapped springs in the study area can provide an additional permanent and cheap source to augment the existing drinking water sources. Furthermore, these springs are located very close to the town of Bsaira which will significantly decrease the cost of the water supply system. According to the annual report for 2020 issued by the Water Department of Tafilah Governorate (MWI, 2020), the amount of water produced within the governorate during the year 2020 amounted to 8056855 MCM, while the amount of water consumed amounted to 8032205 MCM. The number of water subscribers during the year reached 18699, and the average per capita consumption of water was 210 liters per day.

This study aims to evaluate the flow rate and quality of three water springs in Bsaira - Tafila area, which are considered as potential drinking water sources. Moreover, several chemical, physical, and biological parameters were tested and then compared with the Jordanian drinking water standards and WHO standards for determining its suitability for drinking usage. In addition to determine what are the threats influencing the quality of the spring water.

2. Study area

Bsaira is a district in Tafilah Governorate, south Jordan. The study area is located between 30°45' - 30°40'N and 35°35' - 35°39' E, with an area around 56 km^2. It is located between the cities of Tafilah and Shoubak, and about 189 km to the south of the capital Amman. The dominated climate is the Mediterranean climate. The study mandate involves the evaluation of the water quality and quantity for three major springs in Bsaira district which are Um Sarab spring, Gharandal spring, and Dana spring (Fig.1).

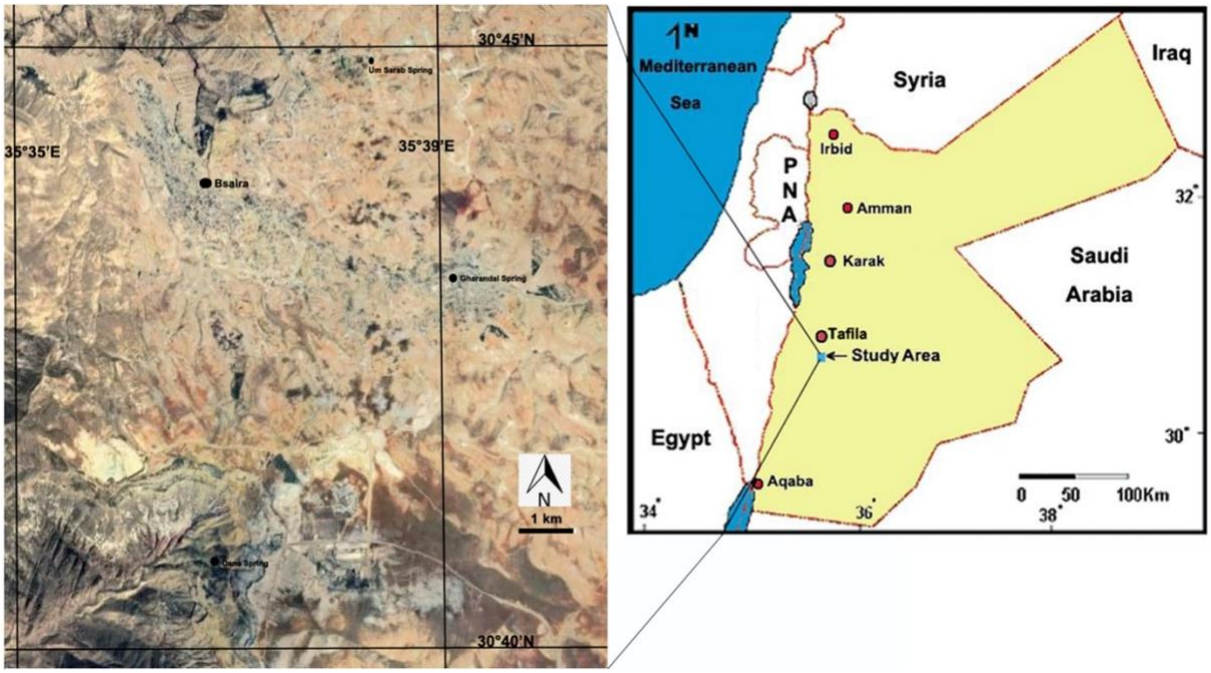


Fig.1. Location map of the study area showing the location of the three studied springs.

The geological setting of the study area (Bsaira - Tafilah) is dominated by the exposure of Upper Cretaceous carbonate rocks (Wadi As-sir Formation), that is limestone layers characterized by hard dolomitic limestone followed by thick carbonate lithofacies with some thin seam of gypsum, beside some nodular chert layers overlain by fossiliferous limestone. Whereas, to the east at Gharandal area much younger lithology is outcropping which is Wadi um Ghudran formation mainly Chalk, interbedded with dolomite, phosphate and sandstone beds. And Amman Silicified Limestone formation dark – grey thick beds of chert interbedded with phosphatic limestone, Oyster and Coquina limestone. Finally, at Dana area, because it is relatively lower in topography as it lies within Wadi Dana, thus much older lithology from lower Cretaceous age Kurnub sandstone formation is outcropping then overlain with the upper Cretaceous Naour-Fuhais-Shua'yb formation which composed of massive nodular limestone layer (Tarawneh, 1987). As for soil in the study area it is a thin soil cover of vertisol type mainly accumulated within gullies due to high relief morphology.

3. Methodology and Materials

3.1. Samples Collection and Water Quality Analyses

Water samples were collected from the three springs during the spring period namely in March, April, May, and June, three water samples were collected from each one of the three springs. All the thirty-six samples were collected using 500 ml sterilized polyethylene plastic containers and 500 ml glass (amber) containers with Teflon-lined caps (for biological analysis). The glassware and polyethylene bottles were soaked in 20% HNO3 and rinsed several times with deionized water before use. Samples were taken from the springs, and care was taken not to touch the bottom of the spring catchment. Sample bottles were resealed and kept in ice boxes, at laboratory they were stored in a clean, cool, dark environment until analysis.

The samples were tested for metals concentrations namely (Ni, Co, Cr, Cu, Fe, Pb, Mn, and Zn) using Atomic Absorption Spectrophotometer, while Cations (Na^+, K^+, Mg^{2+}, Ca^{2+}) were analyzed using the Flame photometer. The pH value was measured using the WTW pH-meter. The total dissolved solids TDS was examined in the laboratory according to standard procedures, as mentioned in (Jiries et al. 2010; WHO & UNICEF, 2017). Chemical Oxygen Demand (COD) was measured using the closed reflux titrimetric method according to standard methods (Ibrahim, 2019). Triplicates of each sample were used in these analyses of each parameter, and the mean was calculated to express the results. The analytical error was within 5%.

The Multiple Fermentation Tube technique was applied for total coliform and E-coli determination in the laboratory according to published protocols (Ibrahim, 2019). The turbidity parameter was evaluated in the laboratory according to the standard procedures (APHA, 2012). In addition, Total Solids (TS) were examined in the laboratory according to standard procedures (WHO & UNICEF, 2017). The average of the samples analysis results during the four months was calculated to express the total results for each water spring.

3. 2. Flow Rate Measurement

The springs discharge measurement was carried out using the container/stopwatch method, one of the simplest and straightforward methodologies for discharge measurement. The time required to fill a container of a known volume is estimated then flow was calculated using the discharge equation by dividing the volume (liters) by time (seconds). The flow rates of the stagnant springs were measured by removing a known volume of water from the springs, marking the drop-down of the water level, and recording the time taken for the water level to recover to its initial value, these methods followed the Domnick et al. (1987).

4. Results and Discussions

4.1. Water Quality Analyses

The Heavy metals and main cations concentrations in the water of Gharandal, Dana, and Um Sarab springs are reported in Tables 1, 2, and 3 respectively. Results show a slightly difference in metal concentrations among the springs. However, the concentrations of all metals in the three springs are below the allowable limits presented in Jordanian and WHO standards for drinking water quality (JS 286/1997). The concentration of the main cations Sodium, Calcium, Magnesium, and Potassium in Gharandal spring Table 1 are significantly higher than their concentrations in the other two springs.

Table 1. The heavy metals and main cations concentrations in Gharandal springs water

Test	Average (ppm)	SDV[1]	Maximum allowable limit Jordan Standard[2]	Maximum Allowable limit WHO[3]	Notes
Cu	0.011	0.0007	2.0	1.5	
Fe	0.0006	0.0001	1.0	0.3	
Zn	0.004	0.0008	4.0	3.0	
Co	0.012	0.0014			
Cr	0.013	0.0005	0.05	0.05	
Mn	0.019	0.0004	0.4	0.5	
Pb	<0.03	-	0.01	0.01	Below detection limit
Ni	<0.02	-	0.07		Below detection limit
Na	31.72	0.890	200	200	
Mg	9.52	0.2260	150	150	
K	12.04	0.2192	50	2	
Ca	191.88	2.008	200	200	

[1] SDV refers to the standard deviation.

[2] Jordanian Drinking Water Standards JS 286/1997

[3] WHO 2004

Calcium is the most abundant cation in the water of the three springs, in Gharandal spring its concentration approached to the maximum permissible limit due to the presence sedimentary rocks of carbonaceous facies around the springs. In general, the results of the metal analysis of the three spring samples show slight differences in metal concentrations except for the calcium in the Gharandal spring. These differences can be related to the depths of springs and groundwater reservoirs, their geological formation, and geographic locations.

Table 2. The heavy metals and main cations concentrations in Dana spring water

Test	Average (ppm)	SDV[1]	Maximum allowable limit Jordan Stanrad[2]	Maximum Allowable limit WHO[3]	Notes
Cu	0.016	0.0033	2.0	1.5	
Fe	0.003	0.0007	1.0	0.3	
Zn	0.006	0.0002	4.0	3.0	
Co	0.017	0.0017			
Cr	0.015	0.0006	0.05	0.05	
Mn	0.062	0.0057	0.4	0.5	
Pb	<0.03	-	0.01	0.01	Below detection limit
Ni	<0.03	-	0.07		Below detection limit
Na	14.92	0.60	200	200	
Mg	7.66	0.6494	150	150	
K	0.872	0.1019	50	2	
Ca	13.75	2.144	200	200	

[1] SDV refers to the standard deviation.

[2] Jordanian Drinking Water Standards JS 286/1997

[3] WHO 2004

Table 3. The heavy metals and main cations concentrations in Um Sarab spring water

Test	Average (ppm)	SDV[1]	Maximum allowable limit Jordan Standrd[2]	Maximum Allowable limit WHO[3]	Notes
Cu	0.009	0.0017	2.0	1.5	
Fe	<0.01	-	1.0		
				0.3	
Zn	0.003	0.0007	4.0	3.0	
Co	0.01	0.0047	-		
Cr	0.01	0.0078	0.05	0.05	
Mn	0.06	0.0016	0.4	0.5	
Pb	<0.03	-	0.01	0.01	Below detection limit
Ni	<0.02	-	0.07		Below detection limit
Na	11.09	0.384	200	200	
Mg	4.25	0.235	150	150	
K	0.93	0.059	50	2	
Ca	12.85	0.183	200	200	

[1] SDV refers to the standard deviation.

[2] Jordanian Drinking Water Standards JS 286/1997.

[3] WHO 2004

The aforementioned results are consistence with the results shown in Table 4 where the higher concentration of total dissolved solids TDS is 479 ppm in Gharandal spring compared to Dana 417 ppm and Um Sarab 251 ppm springs. This is partly due to the different geological formation of rocks that hosted the springs and the lower pH value in Gharandal spring which reduces cations precipitation. In addition to TDS, the pH value, and chemical oxygen demand (COD) results for the water of three springs are shown in Table 4.

Table 4. Some physical and chemical parameters of springs water

	COD Ppm	pH	Turbidity NTU	TDS ppm	TS ppm
Um Sarab	<15	7.41	0.5	251	301
Gharandal	<15	7.13	0.9	479	533
Dana	<15	7.63	0.8	417	458
Jordanian Drinking Water Standards JS 286/1997		6.5 - 8	5	1000	-
WHO 2004	80	6.5-8.5	25	1000	1000

The results of the pH test for the three springs samples showed that their water is neutral to slightly alkaline. The maximum pH value was recorded for the water of Dana spring 7.63, while the minimum value of pH was 7.13 for Gharandal spring. This slight difference in pH values could be due to the change in the geological formation and the type of rocks in the surrounding areas of each spring. It is worth noting that the pH values are within the allowable limits of the Jordanian drinking water standards. The COD concentration of the three springs waters is below the measurable limits, which refers to the very low concentration of organic matter or the absence of organic matter in the water of all springs. The turbidity values of the three springs less than 1 NTU are low compared to the permissible limit (about 5 NTU) which indicates a very low suspended solids concentration.

The results of biological quality parameters (Table 5) include the determination of the number of both total Coliform & E-coli bacteria. The results show the presence of Coliform bacteria and Ecoli bacteria in the water of all springs. The number of total coliform and E--coli bacteria were 7,4 and <1 NTU in Um Sarab, 2420 and 73 NTU in Gharandal, 201 and 17 NTU in Dana spring respectively. These numbers exceed the allowable limits for drinking water standards. The biological pollution of springs water took place due to non-compliance with Jordanian standards for groundwater sources protection zones, which include dividing the surrounding areas into three zones. The first zone is known as the spring head protection zone it extends from 10 to 20 meters around the spring and is often gated and includes artificial feeding facilities and swallowing holes. In the first zone, it is recommended to ban any activity that directly affects the spring and leads to mechanical damage and pollution.

Table 5. Biological water quality parameters

Spring name	Total Coliform	E-coli	Unit
Um Sarab	7.4	<1	MPN/100ml
Gharandal	>2420	73	MPN/100ml
Dana	201	17	MPN/100ml
WHO 2004	0	0	Not detectable in 100 ml sample

The second zone, known as the indoor protection zone, is recommended to prohibit any kind of contamination related to fecal microorganisms and pathogens. Therefore, it is recommended to prohibit the presence of any cesspits, polluted water, or the use of liquid organic fertilizers. The second zone extends around the spring head, between several tens to several hundred meters. It is measured by the 50-day travel time of water which depends on the velocity of groundwater flow and the slope of the area.

Urban which have many mixed activities and practices are causing heavy metal pollution to the various environment components (i.e. soil, water and plants) (El-Hasan and Lataifeh, 2012; El-Hasan and Al-Tarawneh, 2020). Particularly, at the rural areas where several residents are working on animal raising, they usually bring the animal to the water sources (i.e. spring). This would consider as main source of pollution, and this may explain why the Total Coliform and E-Coli was recorded in the studied spring water.

As for the third zone, known as the external protection zone, it is recommended to ban the use of persistent or mobile pollutants Therefore, the presence of gas stations or sewage treatment plants, etc. is prohibited in this zone. After field investigation and comparing the conditions of groundwater resources protection zones with the reality of the three springs, the following observations were recorded:

For the three springs in protection zone 1, there is agricultural activity namely vineyards and figs trees while in protection zone 2 there are houses that have cesspits, in addition to the presence of agricultural activity represented in raising livestock, poultry, crops and fruit trees, belonging to these houses. There are also vineyards, and it is worth noting that these livestock that are raised in this area drink from the springs directly. More houses that have septic tanks were found in zone 3 because the area is not served by the sewer system yet. The activities in the surrounding zones of the springs which contradicts Jordanian standard of groundwater resources protection zones, explains the presence of high numbers of fecal coliform and E-coli bacteria springs water. Therefore, measures should be taken to prevent springs water pollution by applying the protection zone standard and removing the pollution sources from these zones to make the water of these spring fit for drinking purposes.

4.2. Flow Rate Measurement

The flow rate of the three springs has been measured in March, April, and June 2021 as shown in Table 6 to study the fluctuation in the flow rate by time.

Table 6. The recorded flow rates of springs water in different periods

Spring	Flow rate l/s		
	March	**April**	**June**
Dhana	4.9	4.81	4.73
Gharandal	6.2	6.00	5.80
Um Sarab (port 1)	2.5	2.40	2.30
Um Sarab (port 2)	3.1	2.90	2.70
Sum	16.7	16.11	15.53

The results revealed that the maximum flow rate have recorded in March by the end of the rainy season, then it was gradually decreased during the dry season due to the decrease in ground water table over time. The total amount of water from the three springs which accounted for more than 1400 m^3/day in March and more than 1300 m^3/day in June considered a significant amount in a water shortage country like Jordan, therefore the removal of all pollution sources and apply the needed treatment of springs water to meet drinking water standard are of high importance.

5. Conclusions

The study revealed the water of three springs (Um Sarab, Dana, and Gharandal), is suitable for drinking purposes after disinfection procedure. The quality of springs water can be improved by removing the pollution sources specially the livestock wrong practices within the protection zones of these springs. The flow rates of the studied springs are significant in terms of fulfilling the drinking water need at the study area, however, further measures should be implemented such as serving the area with sewerage system.

Acknowledgements

This research was financially supported by the Deanship of Scientific Research-Mutah University. The authors are grateful to the staff of Prince Faisal Center for Dead sea, Environmental and Energy; Research for their efforts in the sample analytical procedures.

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