



ARTICLE

Pollution Aspects Interconnections to Socio-economical impact of Natuf Springs-Palestine

Anwar Atta¹ Marwan Ghanem^{2*}

1. Birzeit University, P.O.Box 14, Birzeit, Ramallah, Palestine

2. Birzeit University, Geography Dep., P.O.Box 14, Birzeit, Ramallah, Palestine

ARTICLE INFO

Article history

Received: 11 December 2020

Accepted: 8 January 2021

Published Online: 31 January 2021

Keywords:

Pollution aspects

Hydrochemistry

Socio-economy

Natuf catchment

ABSTRACT

This study aims at determining the types of pollutants and their sources for the springs in the Natuf catchment/Palestine in addition to evaluating the socio-economic environmental impact on water utilization from residential people. Twelve spring water samples were collected for hydrochemical qualitative analyses of major and trace elements as well as microbiological analyses in the summer of 2017. Plotted spring water samples on the Piper Diagram indicated the water type of Mg-Ca-HCO₃- and eleven samples could be classified as fresh water. Fifty questionnaires were distributed to the farmers and land owners in order to study the impact of socio-economic and environmental conditions for the spring water utilization. The study shows that 90% of local people are using the springs for agricultural purposes. The spring water chemical analysis indicates that they are free from industrial pollutants in regards that 84% of them are located away from the dumping sites. The study shows that respondents are not interested in rain water harvesting during winter season, because 44% of them have their own cisterns. The existence of the water network as well as the absence of the related authority role's contributes to the reduction of people's dependence on spring water. The results will be used for the qualitative aspects potentiality of the appropriated rainwater harvesting techniques to be installed in the area. It is recommended to establish a qualitative monitoring network in Natuf watershed as well as for the springs of the other catchments in the west Bank.

1. Introduction

The quality and quantity of spring water varies over time and space, and is influenced by natural and man-made factors, including climate, hydrogeology management practice and pollution. Access to drinking water in sufficient amounts and good quality is everyone's right^[1]. Water is the key to life and human activity^[2-4]. However,

natural causes such as weathering and erosion of bedrocks, ore deposits, climate change and anthropogenic activities (agriculture, urbanization, and industries) adversely affect and limit the use of the groundwater for drinking and irrigational supply^[5,6]. The degradation of water quality has various direct and indirect impacts on human health. In the West Bank, the domestic and agricultural water demand has increased in the last few decades in regards to

*Corresponding Author:

Marwan Ghanem,

Birzeit University, Geography Dep., P.O.Box 14, Birzeit, Ramallah, Palestine;

E-mail: marwan.ghanem2012@gmail.com

100 ml sterile glass bottles were used for collecting samples for microbiological tests of total coliform (T.C) and fecal coliform (F.C). Fifty questionnaires were distributed randomly to the landowners and the farmers in order to understand the socio-economic and environmental conditions in the study area. The questionnaire consisted of four main parties; the first one is personal information such as age, educational level, sex and job. The second part is related to the frequency of use of springs water and the dangers that affect them. The third part is about the effects of farm land reclamation on the quality of the springs through using fertilizers and pesticides, and the last part is the rainfall harvesting and spring water management. Data of questionnaires were analyzed using SPSS software.

2.3 Results and Discussions

(1) Physical and hydrochemical characteristics of springs

Results of physical parameters of the spring water samples are summarized in Table 1. According to TDS, EC and HCO_3^- results, water can generally be classified as fresh water which is suitable for all purposes (household and farming). The values of TDS and EC for all water samples are ranging between 294-642 mg/L and 650-1120 $\mu\text{S}/\text{cm}$, respectively. The maximum value of TDS and EC was recorded at Abu Danfora spring with 624 mg/L and 1120 $\mu\text{S}/\text{cm}$ respectively. The possible causes of this are mixing with treated effluent that discharges from the Al-Tirah wastewater treatment plant, and the proximity the of springs to agricultural areas. The relationship between TDS and EC of spring water of the study area is strong and TDS versus EC values showed that the value of the linear correction coefficient R^2 is close to the one shown in Figure 2.

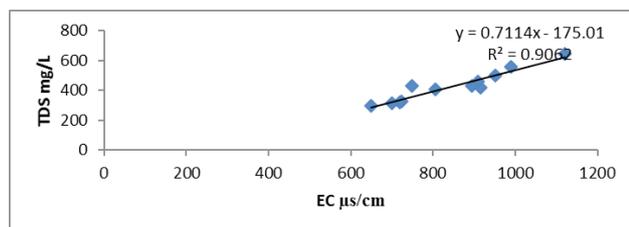


Figure 2. Relationship between TDS and EC for springs water in Natuf catchment area

The pH values for all samples were within the normal range 6.8-7.1 with a mean of 6.9, which reveals that all inorganic carbon exists as bicarbonate (HCO_3^-). The measured temperature of all springs, which is considered as a sensitive indicator for monitoring of groundwater, ranges

between 21.6-24.6 °C with an average of 22.9 °C.

Table 1. Statistical values of physical parameters for spring water samples in the study area

Spring's Name	TDS mg/L	EC $\mu\text{S}/\text{cm}$	DO mg/L	T C°	PH
Wad Reya	501	951	6.8	21.6	6.95
Al-zarka, Beitillu	420	915	5.7	24.6	6.89
Ein Arik Al-tehta	405	805	7,05	22.6	6.92
Ein- Arik Al-Fuqa	294	650	7.6	22.2	7.05
Ein Ayoub	460	910	6.4	21.9	6.99
Al-zarka, Abud	430	748	5.9	22.6	7.08
Al-balad	431	895	7.6	24.3	6.81
Al-qus	320	720	7	24	6.93
Popin	326	723	6.5	22	7.01
Wad Al-limon	560	990	6.2	22.7	6.77
Om Al-roman	315	700	5.25	23.2	6.84
Abu Danfora	642	1120	5.30	24	6.79

Results of the cations and anions hydrochemical parameters are listed in Table 2. Ca^{2+} concentrations of spring water samples varies from 5.29 mg/L in the Al-qus spring to 19 mg/L in the Abu Danfora spring with a mean of 9.7 mg/L. The higher concentration of Ca^{+2} in Abu Danfora spring likely relates to a longer water contact time (residence time) with minerals, and a continuous weathering process of soil and bed rocks. Mg^{2+} analysis showed that there is no significant difference among Mg^{2+} concentrations between spring water samples. Results of K^+ for all studied samples showed that there is no source (anthropogenic) that may increase concentrations of K^+ since concentrations were below the limited value of the WHO guidelines. The concentration of Na^+ for all water samples ranges between 10 - 31 mg/L with the exception of Abu Danfora spring, which is recorded as the highest value of 76 mg/L (Figure 3). This high value is due to the mixing process of treated effluent that discharges from the nearby Alterih wastewater treatment plant, in addition to the farming activities and use of fertilizers around the spring.

Table 2. Analyzed hydrochemical parameters of the spring water samples (in mg/L) and their correlated WHO standards.

Spring's Name	Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	HCO ₃ ⁻	Cl ⁻	SO ₄ ²⁻	NO ₃ ⁻
Wad Reya	7.5	21.2	14.5	0.5	177	33.8	23	7.1
Al-zarka, Beitillu	11.9	24.2	19.3	1.5	182	33.1	23.8	6.5
Ein Arik Al-tehta	11.8	16.9	31.8	5.2	201	35.2	16.8	6.1
Ein- Arik Al-Fuqa	5.4	15.2	12.8	1.2	183	34.5	23.7	8.7
Ein Ayoub	9.2	19.7	26.1	1.4	166	36.2	18.5	7.8
Al-zarka, Abud	5.3	12.4	14.3	0.6	193	38.3	26.5	6.9
Al-balad	11.7	25.6	23.3	0.8	188	45.2	20.8	8.5
Al-qus	5.3	17.6	11.6	0.6	168	36.7	18.7	8.1
Popin	9.6	16.5	12.1	0.97	178	40.2	29.8	8.2
Wad Al-limon	10.7	11.3	12.5	0.49	192	49.8	21.2	7.9
Om Al-roman	9.4	17.2	9.9	1.16	209	33.2	27.3	6.6
Abu Danfora	19	15.3	76.4	2.72	205	39.4	23.9	6.9
WHO Standard	75	30	200	10	100	250	150	45

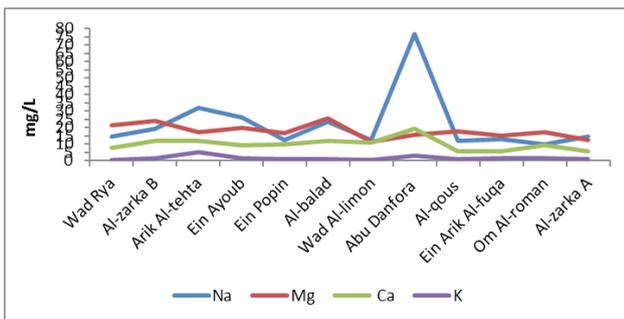


Figure 3. Concentrations of cations for spring water in the study area

Concentrations of NO₃⁻ in groundwater can generally be affected by cesspits, farming activities (fertilizers), septic tanks and animal manure. Concentrations of NO₃⁻ for all water samples range between 6.1-8.7mg/L which is well below the WHO standard limit of 50 mg/L (Figure 4).

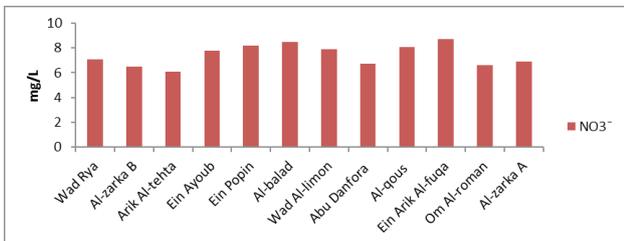


Figure 4. Nitrate concentrations for spring water samples in the study area

The acceptable level of bicarbonate in drinking water should be less than 500mg/L^[14]. The measured values of HCO₃⁻ for all samples were less than the limited value of the WHO and range between 166-209 mg/L, which proves the suitability of using these springs for drinking purposes. The highest concentration could be recorded in the dry season due to the longer residence time of water with dolomite and limestone.

Based on the Palestinian standards for drinking purposes, the standard level of Cl⁻ is 250 mg/l and the concentration of SO₄²⁻ is up to 250mg/L. The measured concentrations of Cl⁻ range from a maximum value of 49.8 mg/L at Wad Al-limon spring to a minimum value of 33.1 mg/L at Al-zarka spring (Beitllu village). All SO₄²⁻ concentrations are below WHO standards.

Generally, the major ions of the analyzed spring water hydrochemical parameters are within the WHO standard methods for drinking purposes, with the exception of Bicarbonate parameter (Table 2). The high concentration of bicarbonate in the analyzed spring water samples is due to the carbonate nature of the aquifer feeding springs in its rock-water interaction processes.

The presence of TOC was recorded only in the springs of Ein Arik Al-tehta and Al-zarka Bietillu, while the rest of samples were free of it. The presence of TOC could be attributed to wastewater contamination, which is verified by the existence of fecal coliform in samples from the same location.

The trace elements concentrations of Ag, Al, B, Ba, Bi, Cd, Co, Cr, Cu, Fe, Pb, Li, Mn, Mo, Ni, Ti and Zn are within the limits of the WHO guideline with the exception of Zn which recorded highest in the springs of Abu Danfora, Al-qus and Al-zarka Beitillu (Figure 5).

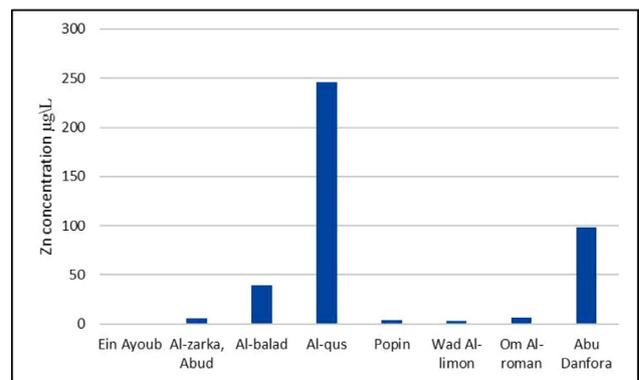


Figure 5. Concentrations of Zn in spring water samples in the study area

Microbiological analysis of water samples showed that the springs of Wad Reya, Al-zarka in both Beitillu and Abud, Ein Arik Al-tehta and Al-fuqa, Popin and Al-balad are contaminated with fecal coliform bacteria, which

indicates the presence of pathogenic micro-organisms in these springs. The highest concentration of fecal bacteria was recorded at Ein Arik Al-tehta with 42 {CFU/100ml} and the lowest one is recorded in Al-zarka Beitillu with 7{CFU/100ml } (Figure 6).

Ghanem et al. ^[15] mapped groundwater quality indicators in Natuf surface water basin and integrate them in the spatial distribution of the surrounding environment. Results were used in a regional water-quality trend assessment and the spring water was found to be polluted in the springs located inside the populated areas. Relationships between different hydrochemical parameters reflect the carbonate nature of the western aquifers. Spring water in the study area is found to be circum neutral to slightly alkaline with average pH ranging from 6.4 to 8.3 and the EC values ranging from 410 to 1307 $\mu\text{S}/\text{cm}$. The average concentrations of anions and cations in all water samples are within WHO standards, with the exception of calcium in some samples. New measurements were uploaded along with historical water quality data to the online mapping and data management system myObservatory, where they could be added to, accessed, and analyzed by multiple users including decision-makers in the study area. Twelve physical and hydrochemical parameters and seven trace elements for water samples during the dry 2003 to wet 2005 seasons, were tested by conventional chemical and instrumental methods from 12 springs and one shallow dug groundwater well in Natuf drainage basin in the western hills of Ramallah district in the West Bank ^[9]. The results show variations in chemical composition between dry and wet seasons and from one spring to another. Springs near populated areas and near agricultural activities show high values of EC, SSP, SAR and TH.

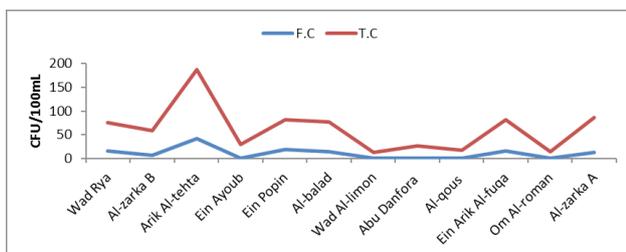


Figure 6. Concentrations of F.C and T.C bacteria for spring water samples in the study area

(2) Socio-economic analyses

Fifty questionnaires were distributed to farmers and land owners who mostly utilize spring water in the Natuf catchment area. The fifty farmers respondents were chosen only for those who are currently using the water springs for irrigation in regards to the majority of farmers

were immigrated from agricultural activities and moved to trade or in building sector in Israel. The questionnaire aims at showing the social, economic and political effects of exploiting the spring water in the study area on its residents' life, and the obstacles that limit their utilization of the spring water, whether they are environmental or political obstacles.

(3) Spring utilizations

Springs are one of the most important water resources in the occupied territories, especially in the Natuf catchment which contains 78 springs in Beitillu village only. The study shows that spring water in the study area is used in farming and for drinking purposes, with 89% from the questioned people using it for farming, 9% of them using it as drinking water and 2% of them using it for other purposes such as constructions. Supposedly, the concerned authorities such as the Palestinian Water Authority (PWA) and Authority of Quality Environmental Assurance and the Ministry of Archeology and Tourism should show interest in the quality and the rehabilitation of the spring water as they are part of national security. However, in the study area, it is found by analysis of the received data from the questioned people that 79.8% of them believe that the authorities do not care about these springs, while 20.8% of them believe that these authorities take care of springs from time to time.

(4) Springs and pollution

Wastewater is considered as one of the pollution sources that threatens the groundwater quality if it disposed raw or not fully treated into the receiving environment. The major urban areas in the study area extend geographically over the high parts of Ramallah, and these high parts are the main recharge area to the Natuf basin. The inadequate disposal of wastewater, especially over the highly permeable areas of the karstic, limestone, will definitely endanger the quality of groundwater. In the study area, the majority of villages are missing sewer systems and people dispose of their wastewater through cesspits or in open areas. Therefore, people were asked whether their cesspits are close to the springs. The answer is 36.7% of springs are located close to cesspits, while 63.3% of springs are not close to them. Even though the vast majority of springs are located far away from the cesspits, the population in the study area disposes of the cesspit's waters by withdrawing it by tanks and then discharging it in the neighboring Wadis, which are close to springs like Ein Qinia and Abud village, which will contribute to groundwater contamination (Figure 7).

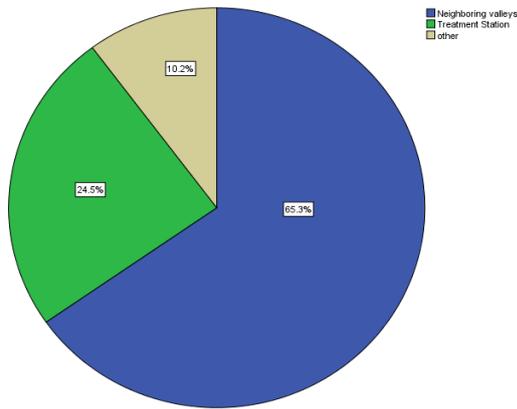


Figure 7. The places where people dispose cesspits contents in the study area

Dumpsites are another source of groundwater pollution and there are no sanitary landfills in the study area, so people tend to dispose their solid wastes randomly near roads, farming lands or close to water resources. People were asked whether there are dumpsites located close to the springs, and 84% responded that springs are not close, while 16% reported dumpsites located near to them, which indicates a potential role of dumpsites in polluting the springs of the study area.

(5) Farming in the study area

Nowadays, the agriculture in the Natuf area has retreated sharply for many reasons related to over population, urban expansion, occupation policy and measures that led to decreasing the importance of agricultural production and farming lands. In the study area, 77.1% of the questioned people cultivated their lands, while 22.9% did not. The results of the analysis to the questionnaires show that 40% of lands are planted with vegetables such as lettuce, parsley, cauliflower, aubergine, while 28.6% are planted with field crops, and 31.4% of them with olives and fruit trees (Figure 8).

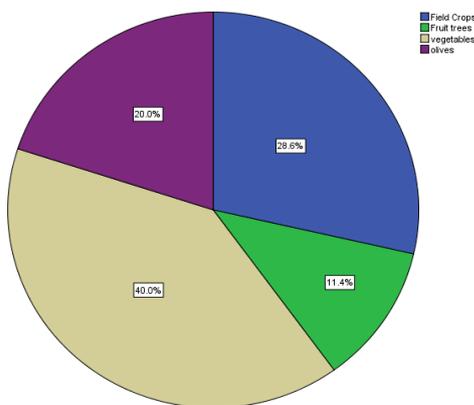


Figure 8. Types of crops that people farm in their lands in the study area

Irrigation methods vary in the study area, as the farmers use three available methods. The study shows that 50% of farmers use plastic pipes for drip-irrigation, while 31% of them directly irrigate their crops as they are close to the springs, and the least used methods is channel-irrigation, which is used especially in the Ein Qinia village because the farm lands are plain terrains and there is abundance of water in this area. Fifty five percent of farms using industrial chemical fertilizers and pesticides and their amounts ranging between 1-5 kg; while 33.3% using 5-10 kg, and 3.7% using 10-20 kg. The percentage of farmers who use more than 20 kg is 7.4%. This reveals the lack of farmer’s awareness toward the use of industrial fertilizers and pesticides, and how these pesticides are affecting the environment and water resources in the area. These fertilizers and pesticides may play a role in contaminating soil and groundwater if they are used excessively. Although the majority of the questioned people practice farming in the study area, farming is not considered as a main career for them, which indicates that farming is not a primary source of income for the families in the area. It is shown that for 75.5% of the questioned people, farming is not the primary source of their income, while 24.5% of them consider it as primary income source. Sixty five percent of questioned people confirmed that their aim of farming in the study area are related to home uses and food consumption, while 34.7% of them farm to sell on the market.

(6) Rainfall harvesting in the study area

The Palestinian population growth in the West Bank has limited water resources which pushed them to look for alternative water resources (Abu-Madi et.al 2008). One of these alternatives is rainwater harvesting. Rainwater harvesting means the capture, diversion and storage of rainfall water for multi-purposes including landscape irrigation, drinking and domestic uses. In the Natuf catchment, it is clear that the questioned people show little interest in rainwater harvesting, with 44.9% of them collecting rainwater in the winter season as an additional water resource to springs in the area, while 55.1% of them do not care about rainwater harvesting, as they feel there is enough water resources availability. Rainfall water is affected by different factors including climatic condition, surrounding environment, storage time of water and roof catchment materials. In the study area, the questioned people show some degree of awareness of the health risks that may be caused by rainwater if it is collected or consumed without cleaning the roof surfaces in the area. The study showed that 64.7% of questioned people clean roof surfaces before rainwater harvesting, whereas 35.3% do not.

(7) Socio-economic and water quality relation for springs in the study area

Table 3. Chi-Square Test in the study area

	Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided) Exact Sig. (1-sided)
Pearson Chi-Square	4.757a	1	.029	
Continuity Correction ^b	3.184	1	.074	
Likelihood Ratio	7.358	1	.007	
Fisher's Exact Test				.044 .027
Linear-by-Linear Association	4.658	1	.031	
N of Valid Cases	48			

a. 1 cells (25.0%) have expected count less than 5. The minimum expected count is 2.75.

b. Computed only for a 2x2 table

Sixty three percent of the questioned people in the study area asserted that the majority of springs are located far away from cesspits. Lab analyses showed that seven water samples out of twelve were contaminated with fecal coliform bacteria, which reveals the impact of human activities on spring water quality. There was a good noticeable match between the results of the distributed questionnaire analysis and parameters lab tests analysis of the spring samples of being water analyses free from industrial pollutants and the answered questionnaire respondents stated that 84% of studied spring are located far away from randomly dump sites and industrial activities. Despite the fact that the majority of farmers are using different amounts of chemical fertilizers ranging between 5-20 kg. However, there is no effect of these fertilizers on the quality of spring water, especially as the chemical analysis of water samples showed that the measurements of TDS, EC, cations and anions were within the WHO guidelines and Palestinian standards for drinking water. The questionnaire analysis showed that the higher percentage of springs in the study area are used for agricultural purposes and not for drinking. This can be attributed to the fact that the presence of internal water network lead to the easy access to water. There is a relation between lack of interest of concerned authorities toward springs and deterioration

of the springs water quality, but it is not statistically significant at $\alpha \leq 0.05$. The questionnaire analysis showed that 64.7% of the questioned people who are cleaning their roof surfaces before rainwater harvesting reflects a strong awareness degree of water quality matters. Based on Chi-Square testing in SPSS, it is shown that there is a relationship between farming and source of income with a statistically significant at $\alpha \leq 0.05$ (Table 3).

3. Conclusions

Assessment of groundwater quality is essential to ensure its suitability for drinking and agricultural purposes. This study was carried out to assess the overall spring water quality and identify major variables affecting the groundwater quality in the Natuf catchment of West Bank and interlinking them with the socio-economic aspects and environmental behavior. Groundwater quality indicators were determined and integrated with spatial information about the surrounding environment. Twelve spring water samples were collected and analyzed for hydrochemical parameters (pH, TDS, EC, DO, Ca²⁺, Mg²⁺, K⁺, Na⁺, HCO₃⁻, Cl⁻, SO₄²⁻, NO₃⁻, TOC) as well as microbiological parameters (F.C and T.C) to ensure the suitability of water for household and farming activists. Results indicated that the spring waters are good enough for farming and human consumption. Seven water samples out of 12 are contaminated with fecal bacteria, which reveals to the anthropogenic impact on water quality. Trace elements for all water samples are within the WHO guidelines except Zn²⁺, which recorded as the highest concentration of 5 mg/L. The presence of TOC was above the detection limit in two of the springs located inside the populated communities and this can be attributed to the presence of wastewater. The study shows that agriculture is not a basic source of income, but rather used for domestic benefits. The study also shows that the existence of Israeli settlements near the agricultural lands and springs have an indirect impact on spring water quality. Relationships between different hydrochemical parameters reflect the carbonate nature of the aquifers. Hydrochemical evaluations show that most springs in the study area are of water type (Ca-Mg-HCO₃). The presence of coliform bacteria and elevated concentrations of trace elements point to human impacts on water quality, and indicate the need for groundwater protection efforts in the study area. A qualitative monitoring system is recommended for the planners of the water and environmental authorities to be installed in the catchment in order to protect its water resources. Water qualitative modeling studies are recommended for monitoring pollution aspects for better water resources management integration.

Conflict of Interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

References

- [1] United Nations. Report of the United Nations water conference. United Nations Publications, New York, Mar del Plara, 1977.
- [2] J. Chen, H. Qian, Y. Gao. Assessing Nitrate and Fluoride Contaminants in Drinking Water and Their Health Risk of Rural Residents Living in a Semiarid Region of Northwest China. *Expo Health*, 2017, 183-32, 195.
DOI: <https://doi.org/10.1007/s12403-016-0231-9>
- [3] Ameer, M., Hamzaoui– Azaza, F., Gueddari, M. Nitrate contamination of Sminja aquifer groundwater Zaghuan, northeast Tunisia: WQI and GIS assessments, *Desalination and Water Treatment*, 2016, 13.
DOI: <http://dx.doi.org/10.1080/19443994.2015.1137495>
- [4] Fallah-Mehdipour E., Bozorg-Haddad O., Loáiciga, H., Climate-environment-water: integrated and non-integrated approaches to reservoir operation. *Environmental Monitoring and Assessment*, 2020, 192:60. <https://doi.org/10.1007/s10661-019-8039-2>
- [5] Ghouili N., Hamzaoui-Azaza F., Zammouri M., Zaghrani M., Horriche F., de Melo, M. Groundwater quality assessment of the Takelsa phreatic aquifer (Northeastern Tunisia) using geochemical and statistical methods: implications for aquifer management and end-users. *Environ Sci Pollut Res*, 2018, 25, 36306–36327. *Environmental Science and Pollution Research*.
DOI: <https://doi.org/10.1007/s11356-018-3473-1>
- [6] Akib- Javed M., Paul A., Nath, T. Peoples’ Perception of the Water Salinity Impacts on Human Health: A Case Study in South-Eastern Coastal Region of Bangladesh. *Expo Health*, 2020, 12, 41-50.
DOI: <https://doi.org/10.1007/s12403-018-0283-0>
- [7] Abed A., Wishahi S. Geology of Palestine: the West Bank and Gaza Strip. Palestinian Hydrology Group: Jerusalem, Palestine, 1999.
- [8] Ghanem M. Hydrochemistry of the Natuf drainage basin in Ramallah area / West Bank. *Journal of Environmental Geology*, 2008, 55(2):359-367.
- [9] Shalash I., Ghanem M. Hydrochemistry of the Natuf drainage basin in Ramalla area/West Bank. *Journal of Environmental Geology*. 2007, 1-6 .
- [10] Ahmed W. The pollution effects of the wastewater flow on the water quality in Wadi Sarida catchment / West Bank. Master thesis. Birzeit University. Palestine, 2015.
- [11] Bader B. The effect of cesspits on water springs pollution of Natuf catchment area-West of Ramallah. Master thesis. Birzeit University. Palestine, 2011.
- [12] Daoud A., Hussein R., Matani M, Swaileh K. Quality assessment of roof-harvested rainwater in the West Bank, Palestinian Authority. *Journal of Water and Health*, 2011:525-533.
- [13] Palestinian Water Authority PWA. Good and Health Water for all report. Ramallah-Palestine, 2009.
- [14] Todd D. Groundwater hydrology. Wiley, New York, 1980.
- [15] Ghanem M., Jebreen H., Sege J., Rubin Y. Impacts of Spring Water Quality Using a Web-Based on the Environmental Management System of Western Ramallah / Palestine. *Euro-Mediterranean Journal for Environmental Integration*.(Springer), 2019, 4: 2.
DOI: <https://doi.org/10.1007/s41207-018-0091-8>