

WATER QUALITY AND RECHARGE OF „BOŠNJACI“ SPRING

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Summary

This paper describes the relief characteristics, climate research of the karst spring "Bošnjaci". The method of recharge the spring is described. Data on the physico-chemical quality of water and bacteriological findings at the time of research of springs, pollutants as well as their origin, zones and measures to protect the site are provided. Finally, recommendations for spring protection are given.

Key words: *water quality, Bošnjaci spring, recharge spring*

INTRODUCTION

The catchment area of the "Bošnjaci" spring is largely located in the Herzegovina-Neretva County, while a smaller part is located in the Republika Srpska. It covers an area of 67.5 km². It is located in Potoci, northeast of Mostar in the settlement of "Bošnjaci". The hinterland of the spring stretches to the settlements of Gornje Zijeplje and Donje Zijeplje.

Geomorphological characteristics of the spring are: the spring belongs to the extreme eastern parts of Bijelo Polje, and the massifs Malo and Veliko Ruište, Crna Gora and the northwestern slopes of the Velež massif with the Pločno plateau and the top of Šljeme, and the Gornja and Donja Zijeplje depression.

"Bošnjaci" spring classified as productive groundwater bodies. Groundwater is the highest quality water when choosing a source for drinking water supply. Behind them are karst waters, then surface waters from relatively clean open streams.

The potential polluters of the "Bošnjaci" spring are considered to be: livestock, recreation centre "Ruište" and the population.

Renewable water resources are subject to the influence of complex anthropogenic factors. Available water is increasingly becoming a factor in limiting economic and social development, and therefore a policy factor (Gleick, 1993).

Potential polluters are stables, manures and livestock. Position of these pollutants is such that they are located in the zone of groundwater direction. The stables and manure stalls themselves are not properly built, and the influences of fecal origin infiltrate directly into the soil.

Recreation centre "Ruište" - Daily frequency of people, in average, in recreation centre "Ruište" is about 50 visitors. During the weekend, the number increases to about 1,000

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people. It was also assumed that the number of visitors will increase over time, in order to develop tourism in this area. Despite that, the sewage system has not been resolved, and wastewater is discharged into the septic tank, which is in poor condition. The centre is supplied with drinking water from the springs Ratkamen and Česim. In the vicinity of the recreation centre, private facilities have been built, which also do not have a sewerage system. Wastewater from these facilities is discharged directly to the ground. Solid waste disposal is another problem of pollution in this area.

One of the biggest potential groundwater polluters in the basin of the spring "Bošnjaci" is the population. The sewerage infrastructure for the settlements in this basin has not been built. Septic tanks that are not properly constructed are mostly used for wastewater disposal. In addition to wastewater, solid waste is disposed of either directly on the ground or in abysses that are directly related to the source "Bošnjaci".

The population bears the largest part of the total burden of pollution of the source "Bošnjaci" in the percentage of 75%, livestock with 23%, while the recreation centre "Ruište" has a very small percentage of participation in pollution (Bešlagić and Hrelja, 2003).

For the use of karst waters, it is necessary to know the natural conditions, the most important of which are knowledge of the position of the main conductors in the basin and underground and knowledge of the flow through these conductors as a function of time.

The relief of this catchment area has karst features. The terrain is characterized by sinkholes, ravines, caves, abysses and karst springs.

Karst springs are of the broken type that form in water-soluble rocks. The most common soluble carbonate rocks in water are (limestone, dolomites and marbles), as well as sulphate (gypsum, anhydrite) and chloride rocks (halite). Bonacci and Roje Bonacci (2000) dealt with the relationship between groundwater and karst cavities, and presented the values of effective porosity, determined at various karst locations in the world, which shows that the effective porosity rarely exceeds 1%. It happens in small and heavily encroached areas such as the area around Salakovac near the Neretva. It analysed the relationship between groundwater and karst cavities using the terms effective and total porosity (Table 1). Total porosity (%), represents the ratio of the volume of all cavities and the volume of the considered karst massif. It varies from 0.2% to 45% in carbonate rocks. Effective porosity (%) represents the ratio of the volume of only those cavities that are interconnected and through which gravitational water moves freely and the total volume of the karst massif.

Table 1. Values of effective porosity n_e %, determined at various karst sites in the world (Bonacci and Roje Bonacci, 2000)

No.	Area name (Country)	n_e %
1.	Hesbaye (Belgium)	3-4
2.	Lamalou spring (France)	2
3.	Brévine valley (Switzerland)	0.2-0.4

4.	Area between Dabar and Fatnica fields (Bosnia and Herzegovina)	6-10
5.	Mendip Hills (Great Britany)	0.92
6.	Area around Salakovac near Neretva (Bosnia and Herzegovina)	2-3
7.	Trebišnjica spring (Bosnia and Herzegovina)	1-3
8.	Trebišnjica basin (Bosnia and Herzegovina)	1.2-1.5
9.	Buško blato (Bosnia and Herzegovina)	1
10.	Cetina spring (Croatia)	0.17
11.	Graba and Rude springs (Croatia)	0.29
12.	Rječina spring (Croatia)	0.23
13.	Central part of the Zrmanja basin (Croatia)	0.31
14.	Ombla spring (Croatia)	1.4-3.5
15.	Karst spring (Lebanon)	3.2
16.	Gornja Zeta (Montenegro)	0.79
17.	Donja Zeta (Montenegro)	0.79
18.	The area between Nikšić field and Donja Zeta (Montenegro)	6.07
19.	The central part of the Tennessee River Basin (USA)	0.4-3.4
20.	The lower part of the Cetina basin (Croatia)	2.5
21.	Upper Silesian basin (Poland)	0.9-3.0

Aeration zones differ from each other in terms of movement conditions and the regime of karst source waters.

During heavy rainfall or long-term rainfall of strong or medium intensity, there is a more intensive recharge of groundwater and thus an increase in groundwater levels. As a consequence of this, the water through the underground flows of different directions of movement (caverns, canals, cracks) received a turbulent flow. This movement of groundwater triggers sedimentary suspended sediment that was introduced into the ground in the previous period, but due to low speeds of movement during the dry period there was deposition of this material in caverns and canals, etc. 6. The movement of sedimentary material of these karst springs. If such bags are captured, during this period when turbidity occurs, water from these sources is discharged from the water supply system until the turbidity of the water drops to the permissible level (Čokorilo Ilić *et al.*, 2018)

The “Bošnjaci” spring belongs to the sub-Mediterranean climate area, with precipitation expressed in autumn and winter. Therefore, summers are dry and hot, and winters are mild.

Temperature and precipitation as climatic factors are interdependent. The character and dynamics of precipitation are significantly influenced by temperature. Depending on the change in temperature and pressure in the lithosphere, the state of water, its structure and properties change (Collins *et al.*, 2013).

Table 2 shows the average monthly temperature characteristics and average monthly precipitation of the catchment area of the “Bošnjaci” spring.

Table 2. Average monthly temperature characteristics (°C) and average monthly precipitation (mm)

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	annual
Average temperature (°C)	5,2	6,5	9,6	13,6	18,0	22,4	25,4	24,9	20,5	15,4	10,6	6,8	14,9
Average precipitation (mm)	141	135	136	131	105	76	45	56	105	154	189	206	1479

Temperature and precipitation affect the recharge of the source itself. It is estimated that the volume of the massif from which the source “Bošnjaci” is fed is about 30 km³. It is fed in a highly karst area by infiltration of precipitation and movement of groundwater through systems of cracks and underground canals formed in limestone masses.

Replenishment of springs occurs through the penetration of surface waters into the ground through the abyss in the area of Hansko polje and Donje Zijeplje.

Groundwater recharge depends on the precipitation regime. If the precipitation regime is inversely proportional to the time difference, then the effect of precipitation is greater on groundwater filling. From the above, it can be concluded that dry periods adversely affect the filling of groundwater. Thus, high temperatures adversely affect the replenishment of springs, because the percentage of water evaporation is high.

The speed of connection of precipitation and surface waters with the karst system is sometimes more pronounced, and sometimes less pronounced, and in connection with that, the impact of these waters on the quality of spring water. The speed as well as the direction of groundwater is checked by inserting markers into the abysses. This groundwater is generally faster to reach springs than those outside these directions (Novaković *et al.*, 2018).

Including the geological and hydrological characteristics of the terrain, hydrological conditions, the position of watershed zones and the results of field research were considered in the decision-making on sanitary protection zones.

Legislation

In order for a public spring to be used for public water supply, it is necessary to meet the legally established norms expressed in the FB&H Law on Waters.

This law clearly prescribes what kind of water should be used to supply the population and industry. It is also stated that the water intended for drinking must not be used for other purposes, and that the areas where the springs are located must be protected by the implementation of sanitary protection zones. Also, this law stipulates that in the area where the springs are located, already existing facilities may not be built or reconstructed. It is forbidden to perform any agricultural work as well as deforestation, as this could jeopardize the health of drinking water.

The control of the health safety of drinking water is performed according to the Rulebook on the health safety of drinking water in authorized laboratories (Official Gazette of B&H, No. 40/10, 43/10 and 30/12). Most of the defective samples of drinking water come from local water supply systems and individual water supply facilities (wells, cisterns, uncaptured springs), in which water is irregularly or not controlled at all. Chlorination of water is often not performed in individual water supply facilities.

Competent public water supply companies perform certain tests of water quality from springs, as well as the quality of water in the network in public water supply systems, and the test results are satisfactory. Groundwater quality tests are performed mainly on those sites where there are sources of drinking water that are in the public water supply systems. These are the sources of drinking water from which the public water supply of the cities of Mostar (Bošnjaci and Buna) and Čapljina (Bjelava) is provided. The quality of water at the Bjelava and “Bošnjaci” springs corresponds to the regulations of the Rulebook.

MATERIAL AND METHODS

All water quality parameters are determined in accordance with the APHA methodology (APHA, 1998). Accuracy of each method is prescribed by the APHA methodology.

Water quality indicators were made in situ and in the laboratory to which they were transported as prescribed by each method. Water temperature, pH and COND were determined in situ. The values of these parameters were measured in the field with a field combined meter Multi-Parameter Instruments. The device has three separate electrodes designed to measure these parameters.

The following were determined in the laboratory: NO_2^- , NO_3^- , NH_4^+ , PO_4^{3-} , SO_4^{2-} , SiO_2 , Fe, Mn, Cl_2 using UV-VIS spectrophotometer, Cl^- , Ca, Mg, permanganate index, alkalinity, acidity, total hardness, carbonate hardness volumetrically, Zn, Cu atomic absorption spectrophotometry, suspended solids gravimetrically all according to APHA methodology. The water quality of the "Bošnjaci" spring for the purposes of this paper was compared between 1999 and 2019.

Bacteriological analysis was performed according to the method BAS EN ISO 9308-1: 2015.

Laboratories conducting monitoring were accredited according to BAS EN ISO / IEC 17025.

RESULTS AND DISCUSSION

The results of the analysis of physical and chemical quality parameters show that the hot water "Bošnjaci" by its basic composition belongs to medium hard waters. The Report on the Quality of Surface and Groundwater Quality in the Adriatic Sea Basin in the FBiH for 2019, published by the Adriatic Sea Basin Agency, states that the chemical condition of the “Bošnjaci” spring is good.

As components of anthropogenic origin that occasionally occur in high waters in "raw" water, they point to the need to implement protection measures to prevent the possibility of "growth" of nitrite in higher concentrations, which are due to uncontrolled human influence within the protected area. The content of Fe, Mn, Zn, Cu, Al is within the permissible limits for drinking water.

Analyzes of bacteriological tests of water from the "Bošnjaci" spring gave results that show that the water is bacteriologically correct. The microbiological opinion is that the water sample complies with the regulations of the Ordinance for treated water.

Based on the obtained results of the analysis, it was concluded that the water from the source "Bošnjaci" can be included in the water supply system with the application of regular standard water disinfection procedures.

Table 3 shows the physico-chemical indicators of water quality of the "Bošnjaci" spring from 1999 and 2019.

Table 3. Physico-chemical parameters of water quality of the "Bošnjaci" spring in 1999 and 2019

Parameters; Units	June, 29 1999	September, 24 2019
Temperature; °C	11.4	12.9
Turbidity FTU (Formazine Turbidity Unit)	1	<0.1
Conductivity; $\mu\text{S}/\text{cm}$	432	419
Suspended solids; mg L^{-1}	0.219	<0.1
pH	7.02	7.5
KMnO_4 ; mg L^{-1}	4.58	0.77
Acidity; $\text{mg CaCO}_3 \text{ L}^{-1}$	84	
Alkalinity; $\text{mg CaCO}_3 \text{ L}^{-1}$	181	200.0
Total hardness; $\text{mg CaCO}_3 \text{ L}^{-1}$	221	120.4
Hardness; Ca; $\text{mg CaCO}_3 \text{ L}^{-1}$	123	179.95
N- NO_2 ; mg L^{-1}	0.011	
N- NO_3 ; mg L^{-1}	0.3	2.94
N- NH_3 ; mg L^{-1}	0.00	<0.039
P- PO_4 ; mg L^{-1}	0.01	
SO_4^{2-} ; mg L^{-1}	45.0	
Cl^- ; mg L^{-1}	4.8	7.0
SiO_2 ; mg L^{-1}	3.68	
Ca; mg L^{-1}	88.4	
Mg; mg L^{-1}	23.9	

Fe; mg L ⁻¹	0.005	41.00
Mn; mg L ⁻¹	0.0	
Zn; mg L ⁻¹	0.01	20.00
Cu; mg L ⁻¹	0.08	
Cl ₂ ; mg L ⁻¹	0.05	

CONCLUSIONS

During the construction of the "Bošnjaci" spring guided the rules prescribed in the Law on Waters. With the construction of this spring and its connection to the water supply system of the city of Mostar, a big step has been made in the water supply of the population. Prior to the connection of this spring to the water supply system of the city, there were planned disconnections of certain settlements from the water supply network. The planned water shutdowns were done due to lack of drinking water. The same water from the water supply network was also used for irrigation, which caused negative reactions from some citizens. The water company appealed for more rational water consumption, and warned of possible exclusions, but most citizens did not listen and did not heed such warnings. This behavior of the citizens was just another glaring example of negligence and carelessness. Since the period of connection of the "Bošnjaci" spring to the water supply system of the city of Mostar, such forced disconnections have not occurred. This speaks of the justification of the construction of this spring and its connection to the water supply network. It is clear that it can be concluded that the citizens of Mostar have gained a lot by releasing this spring into the public water supply.

To avoid a water crisis in the future, with limited and finite water resources, water use must be much more rational and efficient than it is today. Water resources should be managed integrally and the concept of sustainable development should be realized. Providing hygienically correct drinking water is an imperative of modern life.

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KVALITETA VODE I PRIHRANA VRELA IZVORIŠTA „BOŠNJACI“

Sažetak

U radu su opisane karakteristike reljefa, klimatska istraživanja krškog vrela "Bošnjaci". Opisan je način prihrane vrela. Dati su podaci o fizikalno-kemijskoj kvaliteti vode i bakteriološkim nalazima u vrijeme istraživanja izvora, onečišćujućim tvarima kao i o njihovom podrijetlu, zonama i mjerama zaštite lokaliteta. Na kraju su date preporuke za zaštitu izvorišta.

Ključne riječi: kakvoća vode, izvorište Bošnjaci, prihrana vrela