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GEOGRAPHICAL AND BIOLOGICAL ANALYSIS OF THE WATER QUALITY OF MORAVICA SPRING IN THE SOKOBANJSKA MORAVICA DRAINAGE BASIN, SERBIA

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Abstract – In this work we performed a geographical analysis of the Moravica spring locality in the Sokobanjska Moravica drainage basin in Serbia, as well as an analysis of the physical, chemical, and biological parameters of the water during a one-year period. The basic sanitary characteristics and physical, chemical, and biological parameters, necessary for understanding locality conditions, were studied, and the saprobity index, class of quality, O/H index, degree of saprobity, degree of trophicity, and category based on the phosphatase activity index (PAI) were determined. Our results point to the need for continual monitoring of the water quality in the spring locality.

Key words: Moravica spring, Sokobanjska Moravica drainage basin, geographical parameters, biological parameters, water quality.

INTRODUCTION

The Sokobanjska Moravica (L= 58 km) is the last larger tributary on the right side of the South Morava river, whose one spring arm grows from the Moravica spring (locality L–1). The specificity of the physico-geographic positon of the basin (605 km^2) where the locality is situated is its geographic affiliation to the mountainous Carpathian-Balkan (middle and eastern parts) and Peripannonian (western part) regions in Serbia. The region incorporates the territory of the central artery of the Carpathian-Balkan mountain ranges in the east, the valley of the South Morava down river flow in the west, the mountains Ozren (1,174 m) and Devica (1,187 m) in the south, and Rtanj (1,156 m) and Rozanj (897 m) in the north. The surroundings of the Moravica spring (L–1), i.e. the Sokobanjska Moravica basin in which it is situated, is known for its significant amount of water relative to Serbia (an average outflow of 6-7 l/sec/km^2), and generally good quality of underground waters. In the geological structure of the eastern part of the basin in which the localty L–1 is situated, carbonate rocks dominate in a state of great cracking, porousness and with poor filtration features (Milinčić, 2009).

From a geotectonic, morphologic, morphotectonic and petrological point of view, the Sokoobanjska Moravica basin is an example of a complex spatial entity. This territory is the meeting place of two big composite geotectonic units of the First rank – the Carpatho-Balkanids and Serbian-Macedonian Mass. The oldest mainland of the Balkan peninsula are located in the western part of the basin and its very eastern parts of the modified edge of the Serbian-Macedonian Mass (SMM). From the aspect of 'plate tectonics', the complexity of the system was formed by the constant movement of geologic units, from

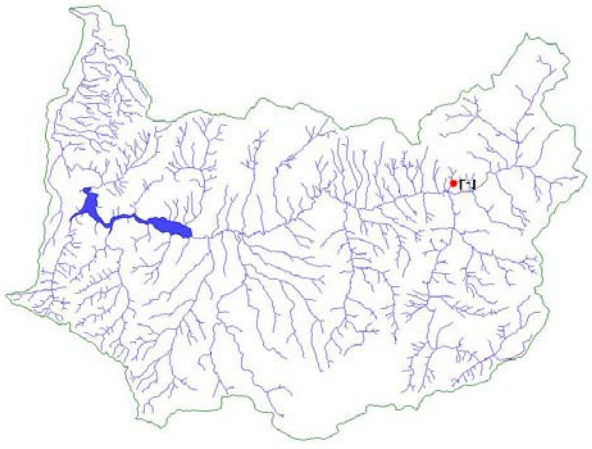

Fig. 1. Geographic position of Moravica spring with the studied locality L–1 in the Sokobanjska Moravica drainage basin, Serbia

the older Paleozoic to the north, by adduction, and agglomeration of the terrain, but also by the collision of the Euroasian continental blocks, i.e. the Mesian plate and Gondwana (Karamata, 2006; Robertson et al., 2008).

The Sokobanjska Moravica is formed by two smaller waterflows – the Izgara and the Tisovik, which both spring up on the slopes of the Devica mountain. They join together at an altitude of 444 m above sea level. Apart from the joints previously mentioned and the Sesalacka River, the Moravica is also supplied with its water by the analysed locality - the Moravica water well (L–1). The locality represents karst water, defined by the coordinates 43°37'48.001"N and 21°59'32.152"E according to the VGS84 elipsoid. It is situated at an altitude of 390 m above sea level, 11 km east from Sokobanja (Fig. 1).

The locality L–1 represents the natural phenomenon of grouped contact karst springs. From a morpho-hydrological aspect, the water well looks like a small core out of which the water flows into the

Fig. 2. Moravica spring locality (L–1)

Sokobanjska Moravica (Fig. 2), draining the eastern part of the karsted mountain massive, Mt. Devica.

The out flow of the water from the locality L–1 is complex (siphon features), and depends on the hydrostatic pressure in the offspring zone and the amount of water in the collector. The water from the locality L–1 is used via the water intake for the needs of the 'Soko' mine. The abundance of the water well varies from 40 l/s, to 2,452 l/s. The surroundings of the locality L–1 traditionally represent campsites (the church of St. Nicholas from 19th century is nearby, as well as Marco's cave).

MATERIALS AND METHODS

Samples of water were collected in February, May, October and December 2004 from a depth of 30 cm. The time from the sampling to the beginning of the analysis was not more than seven hours. In winter, due to the inaccessibility of the terrain, the samples were kept in a fridge and analyzed as soon as possible (Zlatković, 2006; Zlatković et al., 2010). The following microbiological, biological and biochemical parameters and groups were analyzed using standard procedures (Greenberg, 1989): an estimate of the number of coliform bacteria (MPN), fecal coliform bacteria (FCB), sulfite-reducing clostridia (SRC), *Proteus* sp., *Pseudomonas aeruginosa, Enterococcus faecalis, Bacillus* sp., aerobic mesophylic bacteria (AMB), total heterotrophic bacteria *sensu lato* (HB), oligotrophic bacteria (OB), amylolytic bacteria (AB), proteolytic bacteria (PB), saccharolytic bacteria (SB), lipolytic bacteria (LB), phytoplankton species, chlorophyll-a concentration and phosphatase activity, was made. Based on these parameters we determined the saprobity index, class of quality, index O/H, degree of saprobity, degree of trophicity and category based on the phosphatase activity index (PAI) (Matavulj et al., 1990).

We also measured the physical and chemical characteristics: temperature, pH, turbidity, specific conductivity, total dissolved substances (TDS), dissolved oxygen, oxygen saturation, consumption of $KMnO_4$, biochemical oxygen demand (BOD) and chemical oxygen demand (COD) (Greenberg, 1989).

For the geographic analysis of the location of the Moravica spring, we used geological, pedological, and topographic maps 1:50,000, as well as the data of the Republic Hydrometeorology Institute in Belgrade.

RESULTS

Geographic analysis of the locality Moravica spring

A tectonic view of the Sokobanjska Moravica drainage basin in whose eastern part the locality L–1 is situated, represents a depression which was formed by the lowering of the terrain along the Sokobanjski, Ozrenski, Sesalački, Rtanjski and Poružnički faults and Gola Mountain (Marković, 1977; Zeremski, 2002; Milinčić, 2009; Zlatković et al., 2010). The lowering of the terrain along the faults was much greater in the western part of the drainage basin. The abovementioned faults determined the direction of the Sokobanjska Moravica River, and its morphophysiognomic characteristics and predisposed the hydrographic network (Zlatković et al., 2010).

Precipitations influence the hydrographic features of locality L–1 in two ways. Firstly, by gravity and hydrostatic plunge, rainfalls penetrate through the cracks and in that way fill the collector. Second, after heavy rain falls the ground waters flow into the Moravica water well through ground rocks; the blocking of water seepage has a negative effect on the microbiological quality of the water at the locality L–1.

The annual precipitation in the Sokobanjska Moravica drainage basin is 663 mm. The maximum is in December while the minimum is in January. The average annual insolation is 1862.4 h, with a maximum in July (267 h or 8.6 h per day) and minimum in December (148 h or 1.5 h per day). The vegetation period starts in March and lasts until November. The distribution of precipitation in the vegetation period is unfavorable.

Table 1. Physical and chemical characteristics of the Moravica spring

Data	27 February 2004	26 May 2004	10 October 2004	5 December 2004	2 February 2005
temperature (°C)	10.0	10.0	10.0	9.8	10.3
pH		7.21	7.28	7.30	7.14
specific conductivity (μS/cm)		200	195	191	192
TDS (mg/l)		176	172	168	169
O_2 (mg/l)	11.36	10.0	10.38	10.54	12.19
O_2 saturation (%)	100.26	88.26	91.61	93.03	107.59
KMnO4 consumption (mg/l)	4.27	4.03	1.93	4.80	5.10
COD (mg/l)	1.07	1.0	0.48	1.20	1.27
BOD (mg/l)	0.87	1.16	1.0	0.66	
NH_4^+ (mg/l)		0,24		0,15	
NO_3^- (mg/l)		1,31			
nitrites (mg/l)		0,0			
total phosphates (mg/l)		0,05			
orthophosphates (mg/l)				0,012	0,013
Cl^- (mg/l)		6,0		7,0	7,0
SO_4^{2-} (mg/l)		11,94			
total hardness (°do)		14,49		17,08	
Ca (mg/l)		89,68		123,27	
Coo (mg/l)		125,52		171,21	
$CaCO_3$ (mg/l)		259,37		305,73	
Mg (mg/l)		8,39			
MgO (mg/l)		13,93			
Ca+Mg (mmolek/l)				12,2	
bicarbonates (mg/l)				305,0	396,5
Fe (mg/l)		0,041			
Mn (mg/l)		0,002			
Pb (mg/l)		<0,01			
Zn (mg/l)		0,012			
Ni (mg/l)		<0,005			
Cu (mg/l)		0,016			
Cd (mg/l)		0,001			

The surroundings of locality L–1 are in the zone of sedimentary rocks. The porous limestone surface causes aridity and a rapid movement of the water under continuous and intermittent streams. On the terrain above locality L–1, the state of regional and local cracking is frequently observed. This creates porousness and causes water seepage through the rocks that affects the fast water fertilizing of the locality. The underground water that comes from the higher terrains moves slowly to locality L–1. As it comes into contact with mineral matter, part of this mineral matter dissolves in the water. In this way, the water from locality L–1 becomes enriched with calcium and magnesium salts and attains the features of hard water. In the same way, the ground water, running through the underground layers, releases itself from the suspended material by natural filtration.

Table 2. Basic microbiological and biological characteristics of the Moravica spring

Data	27 February 2004	26 May 2004	10 October 2004	5 December 2004
MPN (cell/100 ml)	0	0	0	0
FCB	-	-	-	-
Proteus sp.	-	-	-	-
SRC	-	-	-	-
P. aeruginosa	-	-	-	-
E. faecalis	-	-	-	-
Bacillus sp.	-	-	-	-
AMB (cell/ml)	$3.90x10^2$	$6.00x10^1$	$3.50x10^1$	$0.60x10^1$
HB (cell/ml)	$1.00x10^2$	$4.35x10^2$	$9.10x10^1$	$7.10x10^2$
OB (cell/ml)	$1.02x10^3$	$1.44x10^3$	$1.76x10^2$	$4.50x10^1$
AB (cell/ml)	$7.50x10^1$	$9.00x10^1$	$2.50x10^1$	-
PB (cell/ml)	$1.50x10^1$	$1.00x10^2$	-	$0.50x10^1$
SB (cell/ml)	$7.80x10^1$	$2.60x10^1$	$1.00x10^1$	$7.50x10^1$
LB (cell/ml)	$3.50x10^1$	$1.80x10^1$	$1.00x10^1$	$2.15x10^2$
saprobity index	0	0	0	0
chlorophyll a(mg/m3)	0.0	0.0	0.0	0.0
PAI (µmol/s/l)	1.01	1.18	3.23	5.70

+/- present/absent

Table 3. Derived biological characteristics

Date	27 February	26 May 2004	10 October 2004	5 December 2004
Class of quality	I	I	I	I-II
Index O/H	10.2	3.31	1.93	0.063
Degree of saprobity	catarobic	catarobic	catarobic	catarobic
Degree of trophicity	atrophic	atrophic	atrophic	atrophic
Categorization based on PAI	II-III	II-III	III-A	III-B

Physical and chemical characteristics of the Moravica spring

Temperature analyses of the water at locality L–1 showed that it is relatively constant during the whole year (from 9.8°C in December 2004 to 10.3°C in February 2005). The values of biochemical use of oxygen are low, while the values of $KMnO_4$ use are to a certain extent higher in comparison to the remaining springs of the karst mountains. Ozren and Devica. Nitrates are present in small concentrations; there is no nitrite, while the amount of ammonium ions varies and exceeds the permissible concentration. Total phosphates, orthophosphates, sulfates and chlorides are present in small concentrations. The spring water hardness values are average to very hard, the ratio of Ca:Mg is 10.68:1, while the other metals are only present in traces.

Microbiological analysis of the Moravica spring

There are no coliform bacteria in any of the analyses of the water of locality L–1. The number of aerobic mesophilic bacteria varies. Sulfite-reducing clostridia, *Proteus sp*., *Pseudomonas aeruginosa*, *Enterococcus faecalis* and *Bacillus* sp. are not found. The phosphatase activity index strongly varies.

Chlorophyll is not found and the water is atrophic, which does not comply with the catarobic sapro-

bity level. The number of heterotrophic and oligotrophic bacteria varies over periods. All physiological groups of bacteria are constantly present, except in two periods. They were registered in numbers of several tens to several hundreds of bacteria per ml. The water complies with the trophic level and saprobity index.

DISCUSSION

The water quality at locality L–1 is satisfactory since during the analyzed period neither fecal type nor any other coliform bacteria were found. The O/H index values, although varying, are mostly high, which is a characteristic of clean waters. The catarobity is in compliance with the atrophicity (completely atrophic and catarobic ecosystem).

The number of aerobic mesophilic bacteria rarely exceeds several tens per ml. In February 2004, after heavy rainfall, the number of these bacteria at locality L–1 exceeded the values registered in later periods. This indicates that external circumstances caused the increase of aerobic mesophilic bacteria number, even in this locality that is, at a first sight, an unexpected place for the occurrence of the mentioned situation. Their increased number mostly coincided with a greater loading of the water, according to the other parameters. The geographic analysis revealed heavy rainfall on locality L–1 which affected negatively the water quality.

The high ratios of oligotrophic and heterotrophic bacteria (O/H index) at the locality L–1, which varied from 10.2 in February to over 3.31 in May and 1.93 in October, to 0.63 in December, reveal an increased ability for autopurification.

The locality L–1 is represented by relative stability in water quality and quantity during the analyzed period. Its stability and fineness depends on the characteristics of the drainage system, atmospheric and other waters that fertilize the locality as well as on the characteristics of the geologic layers, the presence and the nature of the soil layer and others. Our analysis has shown that the increased amount of precipitation that penetrated into the locality through the ground layers in February 2004, rapidly deteriorated its microbiological quality. For these reasons, the continual monitoring of the water quality is an essential precaution measure in protecting locality L–1.

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