PRELIMINARY RESULTS ON THE QUALITY OF DRINKING WATER SOURCES IN THE RUNCURI PLATEAU

DANIELA BORDA[1], LAURA EPURE, IOANA NICOLETA MELEG[2], IOAN COCIUBA[3]

Abstract. We developed a comparative study, between the 2009-2010 and 2015-2016 sampling campaigns, in order to monitor the changes occurred in the quality of seven drinking water sources, after few springs from the Runcuri Plateau were taped into the locals' homes. A special view was given to the geology of the Runcuri Plateau and to the relationship between the geological substrate and physicochemical profile, microbial content, and invertebrate communities of the analyzed springs. The particular geology of every drinking water source allowed us to understand why their physicochemical and biological features are different, even if springs are close to each other. Also the trends over space and time, as well as the seasonal variations were analyzed, in order to contribute to a better understanding of the geochemical and biological constraints, specific to the groundwater ecosystem functioning in karstic areas. Our results emphasized the anthropogenic impact on the drinking water quality, which was higher in the 2015-2016 sampling campaigns. The anthropogenic pollution was assessed through the following parameters: ammonium, nitrite, nitrate, phosphate and faecal coliforms including *E.coli*, which reflect the vulnerable nature of the drinking water sources on the marginal limits of the plateau. The groundwater fauna responded to the organic pollution by a pronounced decrease in diversity and abundance in 2015-2016. Taking into account these results, specific protective measures must be considered, in order to maintain the quality of the drinking water sources used by the inhabitants of the Runcuri Plateau. The results of this study may have relevant implications for public health and for the sustainability of the rural communities of karstic regions. In addition, our results provide a reference background of the local groundwater status, which can be used in further investigations and monitoring.

Key words: karst plateau, springs, physicochemical parameters, microbial hazard, water invertebrates, anthropogenic impact, organic pollution.

1. INTRODUCTION

Karst represents a special and a fragile environment, with particular hydrology. It includes surface and subsurface components, especially vulnerable to pollution, due to water velocity and thinness of the cover soil overlying the bedrock (WHITE, 2005, LECOMTE *et al.* 2016). One of the most important features of the karst is the water storage capacity. It is known that karst waters represent about 25% of the

drinking water supply in the world (PARISE and GUNN, 2007). Around 75% of the European Community inhabitants use groundwater as drinking water, and for domestic or industrial purposes (DANIELOPOL *et al.* 2008). Unfortunately, this main resource is strongly vulnerable to human activities, which actually negatively affect it (PARISE and GUNN, 2007). The anthropogenic interventions may influence different aspects of the water circulation, or may disrupt the natural equilibrium throughout pollution (BONACCI, 2015). Because karst springs represent the drainage outlets of the area's natural conduit system, they may easily be contaminated, from surface, with water soluble contaminants (WHITE, 2005). Without sanitation systems and adequate water treatments, which are not implemented in less developed regions, the drinking water sources may rapidly be pathogenically polluted and may spread waterborne diseases. Therefore, the local communities are directly exposed to risks of illnesses and diseases by consuming the contaminated water.

Monitoring the groundwater status represents a useful method in diagnosis of the existing impact and of the anthropogenic stressors, and for detecting the warning signs of the ecosystem deterioration and microbial pollution in early stages. In the last years, an integrative ecological assessment of the groundwater quality and the ecosystem status that includes physical, chemical, and biological criteria started to be developed (STEIN *et al.* 2010).

Based on the karst geology we used an ecological approach applying methods for physicochemical, microbial and water invertebrate assessments, purposed to investigate the quality of the springs that are used as drinking water by a rural community from the Runcuri Plateau (Apuseni Mountains, Romania), as well as the seasonal and time-dependent variations, of the water parameters. In the same time, a good knowledge of the local geology explain the water chemistry and the changes in the water properties, in different parts of the area. Therefore, the data obtained in the present study will offer valuable information about different aspects of the water quality, in a representative karstic plateau, the anthropogenic impact, and the specific protection measures that can be applied, in order to diminish the aquifer pollution.

2. GEOLOGICAL FRAMEWORK AND AREA DESCRIPTION

2.1. GEOLOGY OF THE RUNCURI PLATEAU

The study was conducted in a restricted karstic region of the Pădurea Craiului Mountains from Western Romanian Carpathians, the Runcuri Plateau (Fig. 1). Having a surface of about 7 km^2 and a 500 m medium altitude, the Runcuri Plateau is a small area, but typical for the Pădurea Craiului Mountains. It is located in the south-western part of the massif, next to the northern side of the Roşia depression, being shaped on the impermeable, softer, rocks of Upper Cretaceous. The geological structure of the perimeter, as well as the entire massif of Pădurea Craiului is prevailed

by Mesozoic deposits, an alternation of detrital rocks, generally impermeable, with thick levels of main karstificable limestone (Fig. 1). In the Runcuri area, the geological succession begins with Lower Jurassic detrital deposits, which exceed 100 m in thickness. At their upper part of the Upper Liassic age, we mention the presence of a limestone level, 10-12 m thick, which retains groundwater and which may generate springs and even caves (i.e. the Ciur Izbuc Cave). The previous deposits are succeeded by Middle Jurassic deposits that contain dominant marls and limestone of 20-30 m in thickness. Generally, these are impermeable and non karstificable rocks. Above these lays a massive Upper Jurassic limestone level that may exceed 100 m in thickness. Discordant, after a short period of under-aerial shaping with bauxite deposition, they are followed by a main level of massive limestone of 200 m in thickness, of the Lower Cretaceous age.

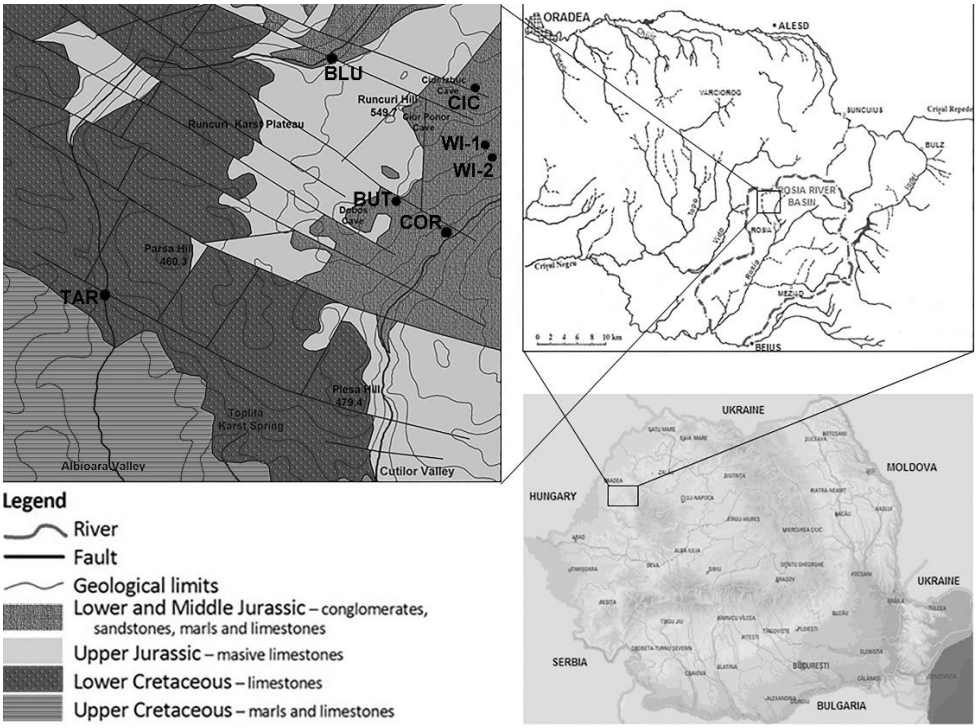

Fig. 1. Geology and hydrology of the studied area, with location of the sampling points.

Due to the solubility of the limestones, the massif has the highest density of caves in Romania, reaching an average of 295.75 m of galleries per km^2 (ORĂŞEANU, 2010). The Runcuri Plateau is formed by few insular hills, sinkholes and dry valleys. It has a complex endokarstic system, "Complexul carstic Ciur – Groapa lui Doboş – Topliţa", which shares a number of five caves, with the water outflow in the Topliţa de Roşia Spring (275 m a.s.l.). These caves are: (1) Ponorul Tinoasei

(539 m a.s.l., water inflow), (2) Ciur Izbuc (535 m a.s.l, 1,030 m length, temporary water outflow and fossil cavities), (3) Ciur Ponor (480 m a.s.l, 17,078 m length, permanent water inflow), (4) Groapa lui Doboş (467 m a.s.l, 319.5 m length, temporary water inflow), and (5) the Topliţa de Roşia Cave, which represents the main outlet of the Runcuri karstic Plateau (GORAN, 1982; RUSU, 1988; ORĂŞEANU, 1991, ORĂŞEANU 2010).

2.2. HYDROLOGICAL NETWORK IN THE RUNCURI PLATEAU

The impermeable part of the Runcuri Plateau shows an erosion with three water collectors: the Albioara Valley in the north, the Cuţilor Valley in the south, and small local streams tributary to the Ciur depression. The whole karstic area of the Runcuri Plateau is drained by the underground stream of the Ciur Ponor – Doboş – Topliţa de Roşia System. The registered minimum discharge is 11 l/s, while the multiannual average discharge is 105 l/s (PONTA, TERTELEAC and GASPAR, 1991). The water sources are of two types: the water that entries the underground through the widespread sinkholes, and the water originating from impermeable areas that riches the underground at the contact with the limestones, Ciur Ponor and Albioara Ponor. The sampled springs belong to the second type, being located in the NE area, where the impermeable rocks of Lower and Middle Jurassic outcrop, and in the lower peripheral area, in the Albioara Valley. In the southern part, other springs appear at the contact between limestone and the impermeable upper cretaceous marlstones of the Roşia Depression (Fig. 1).

2.3. CLIMATE, VEGETATION AND HUMAN COMMUNITY

In the Apuseni Mountains, the climate is temperate-continental with the multiannual average values of temperature range from +4^{o}C and +8^{o}C, and an average temperature between -5^{o}C in January, and +16^{o}C in July. The multiannual average values of rainfall range from 800 and 1200 mm (ORĂŞEANU, 2010). The vegetation consists mainly of large pastures, hayfields, agricultural crops, and deciduous forests. The Runcuri Plateau includes a small rural community, formed by 4 farms, 16 households, among which 5 pensions and 1 touristic complex with a capacity of 40 guests. Because the former exploitation of bauxite lens was interrupted about 20 years ago, nowadays the human activities are mostly represented by farming, animal breeding, and tourism. The land is exploited in a traditional manner, inhabitants practicing agriculture for personal necessities, using animal-powered mechanization, organic fertilizers, and usually no chemical treatments. In this area, the farms are not connected to a public water network and the households have no water treatment system. Only few drinking water sources are available for domestic use. All of them are springs located at the periphery of the karstic area, and seven of the most used drinking water sources were sampled in our study (Fig. 1).

3. METHODS

3.1. SITE DESCRIPTION AND PROCEDURE

In order to determine the quality of the drinking water sources used by the rural community of the Runcuri Plateau, we collected water from seven springs: five from the karst Plateau, and other two from the Albioara Gorges, which represent the drainage area of the plateau (Fig. 1). We did not include in this study water sources that are not utilized as drinking water supplies, such as the Albioara sinkhole and the Topliţa de Ţarina karst spring. To get a more accurate image of the water quality and the evolution of the pollution processes in time, we performed two sampling campaigns: the first campaign (1st) took place in 2009-2010 and the second campaign (2nd) in 2015-2016. For every campaign we sampled the water sources seasonally: autumn (Au), winter (Wi), spring (Sp) and summer (Su). After 1st results, and aiming to obtain more data concerning the pollution of the entire Runcuri Plateau, in 2nd we decided to monitor the 7th spring, which drains the northern part of the Runcuri Plateau.

For a better understanding of the particularities of each spring, we provide a description of the sampling sites:

(1) The Ciur Izbuc Cave Spring (CIC) is located next to the Ciur-Izbuc Cave, about 80 m east of it. Although only sandstone fragments are found nearby, the water source is most likely derived from an 8-10 m-thick limestone level, of the Upper Liassic age, in which also the cave was developed. The spring is limnocrene, with a clay substrate and a little artificial dam made from tree branches (L/l/h: about 2m/1.5m/0.4 m).

(2) The Buturugă Spring (BUT) is originated in Middle Jurassic sediments. It is located in the northern part of the same large sinkhole from where the Doboş Cave begins, which represents the place where the water re-enters the underground. The spring is limnocrene, with sandstones and marl substrate. It has an artisanal catchment, inside a large hollow of a cut tree trunk (about 0.6 m diameter and 2 m depth).

(3) The Cornelia's Spring (COR) is originated in an thin Upper Liasic limestone level, the same level in which the Ciur Izbuc Cave developed. But the COR spring is constrained by the presence of a fault with a NNW-SSW direction. It is limnocrene, being arranged for human necessity and closed with a wood door (L/l/h: about 0.5m/0.7m/0.6 m).

(4) The 1st Water Intake Spring (WI-1), and

(5) The 2nd Water Intake Spring (WI-2) are two springs collected together in a common cement reservoir that was recently arranged for drinking water distribution in the touristic complex and farms nearby. WI-1 is located in the NE part of the perimeter, bordered by lower Jurassic quartzite sandstones. This spring is constrained by a marlish level from Lyasic succession. It has the highest volume flow rate of the two springs collected together. WI-1 was previously arranged with wood materials

and was locally used by the inhabitants. Now the spring water is collected in a cement edge with a marlish floor and a wood top (L/l/h: about 1.5m/0.8m/0.6 m). The water excess is drained through a short pipe into the common cement reservoir, arranged near WI-2, which has lower volume flow rate than WI-1. WI-2 originates in the same Lower Jurassic sandstones and is situated about 30 m distance from WI-1, on lower altitude; it has a sandstone substrate too. We sampled the limnocrene part for WI-1 and WI-2.

(6) The Ţarina's Spring (TAR) is located in the left slope of the Albioara Gorges, downstream, ahead of the first houses of the Ţarina village. It represents a local and marginal drainage of Lower Cretaceous limestone from the Runcuri Plateau. The spring is reocrene, has a limestone substrate, and a little basin, formed by a cement barrier (L/l/h: about 0.2m/0.8m/0.15 m). We sampled the limnocrene part of this spring.

(7) The Blue Spring (BLU) is located upstream of the Albioara Gorges, next to a forest range, near the access road to the Runcuri Plateau. It originates from the base of the Upper Jurassic limestone, at the contact with the impermeable marl deposits of Middle Jurassic. The spring, collected in a big cement basin (L/l/h: about 4m/3m/1.3 m), has the biggest volume flow rate of the studied springs. We sampled the basin water, because the spring is piped and inaccessible.

Excepting BUT, TAR and BLU, which are only partly shaded by deciduous trees, all the other water sources are surrounded by rich forest vegetation.

3.2. WATER ANALYSES

Four sets of data were determined in every water sample: the physical parameters, the chemical analysis, the microbial content and the invertebrate diversity and abundance.

Physical and chemical parameters. Using a Portable Multiparameter HI 9828 (Hanna Instruments) we measured, on site, the water temperature (t ^{o}C ± 0.15^{o}C accuracy), pH (± 0.02 pH accuracy), the dissolved oxygen (DO ± 1.5% readings accuracy), the electrical conductivity (EC ± 1µS/cm accuracy), and the total dissolved solids (TDS ± 1 mg/L accuracy). Nitrates (NO_3^-), nitrites (NO_2^-), ammonia (NH_3), phosphorus (P), iron (Fe), calcium (Ca) and magnesium (Mg) hardness concentrations were determined with a portable Multiparameter-Photometer C99, HI 83099 (Hanna Instruments), based on colorimetric methods and on the absorbance measurement.

Microbiological analyses. Microbiological analyses quantified the viable colony forming units (CFU) from 1 ml of sampled water. We used the following media cultivation plates: RIDA®COUNT Total to determine the total bacterial counts (TBC), RIDA®COUNT *Escherichia coli*/Coliform for *Escherichia coli* (Ec) and total coliform

(TC) counts, and RIDA®COUNT Yeast&Mold Rapid, with the mention that the yeasts and molds (Y&M) were measured only in the second sampling campaign. After 48 hours of cultivation at 36°C, readings of bacterial growth were scored. For Y&M, readings were taken after 72 hours of cultivation at 25°C, respectively.

Water invertebrates. Water invertebrates were collected on all sampling sites by qualitative filtering, using a 65 μm net. The invertebrates were preserved in 70% alcohol, then counted and sorted in taxonomic groups, in laboratory, using a stereomicroscope (OPTIKA Microscopes Italy, model SZR).

The water quality and the contamination levels were discussed according to the Romanian standards for drinking water quality (L 458/2002, the synthetic form on 6th September 2017), with adjustments and completions added by the subsequent laws.

3.3. STATISTICAL ANALYSIS OF DATA

In order to have a global view on the time variations of the physicochemical and biological characteristics of the Runcuri Plateau groundwater, we calculated the annual averages in each campaign (1st and 2nd). These mean values included one-year measurements recorded seasonally, from all station, for every parameter. To observe the seasonal trends we calculated the averages for each season (Au, Wi, Sp and Su). These mean values included the measurements from all stations, in each campaign, and for every parameter. To have a spatial view of the physicochemical and biological variation in the studied Plateau we calculated the site annual averages. The site averages included one-year measurements recorded seasonally, in each campaign, and for every parameter.

Student's t-test was performed in order to determine the statistical significance between the parameters measured in 1st versus 2nd sampling campaigns, and also between different seasons.

4. RESULTS

4.1. PHYSICOCHEMICAL PARAMETERS

According to the Romanian standards for drinking water quality (58/2002 Law), an overview of the measured physicochemical parameters, taken individually, showed that some values exceeded the maximal limit. Most of them were due to the high nitrites concentrations, and few due to the high concentration of NO_3^-, NH_3, and Fe, but also due to the low concentrations of pH or DO (Tab. 1).

Table 1

The individual physicochemical values of the springs from the Runcuri Plateau, which exceeded the standard limits. 1st, 2nd represent the campaigns of the water sampling; Au, Wi, Sp, Su represent the sampling seasons: autumn, winter, spring, summer. The measurements that were within the legal standards of drinking water quality were not listed here (for means of these values see Figs 2 and 3)

Standard limits	***pH (>/= 6.5; </= 9.5)***		***Nitrates (50 mg/l)***		***Nitrites (0.5 mg/l)***		***Ammonia (0.5 mg/l)***		***Fe (0.2 mg/l)***	
Sampling	***1st***	***2nd***	***1st***	***2nd***	***1st***	***2nd***	***1st***	***2nd***	***1st***	***2nd***
CIC		6.15 (Wi) 6.35 (Su)			0.619 (Au)	3.00 (Au) 1.00 (Wi) 11.00 (Sp)				0.50 (Au)
BUT		6.28 (Su)				3.00 (Au) 3.00 (Wi) 6.00 (Sp)		0.52 (Au)	0.26 (Sp)	
WI-1						30.00 (Au) 8.00 (Wi) 3.00 (Sp)				0.90 (Au)

Table 1 (continued)

WI-2						5.00 (Au) 11.00 (Wi) 1.00 (Sp)			0.42 (Au)
COR						9.00 (Au) 1.00 (Wi) 3.00 (Sp)		1.36 (Au)	
TAR		6.34 (Su)	70.88 (Sp)			46.00 (Au) 36.00 (Wi) 1.00 (Sp)		1.52 (Au)	
BLU		6.26 (Wi) 6.40 (Su)				3.00 (Au) 12.00 (Wi) 5.00 (Su)			

Figure 2a shows the spatial variation of the physicochemical characteristics of the water sources, based on the annual means of the measured parameters, in each sampling site. These means masked some individual measurements that exceeded the maximal limits of the water quality standards. Nevertheless, in 2nd, the mean value of dissolved oxygen was below the mentioned quality standards at one spring (BUT), nitrites mean value was maintained above the maximal standards in all springs, the mean of ammonia was above the standards at three springs (TAR, COR, and BLU), while the iron concentrations also exceeded the standards at WI-1 spring (Tab. 2).

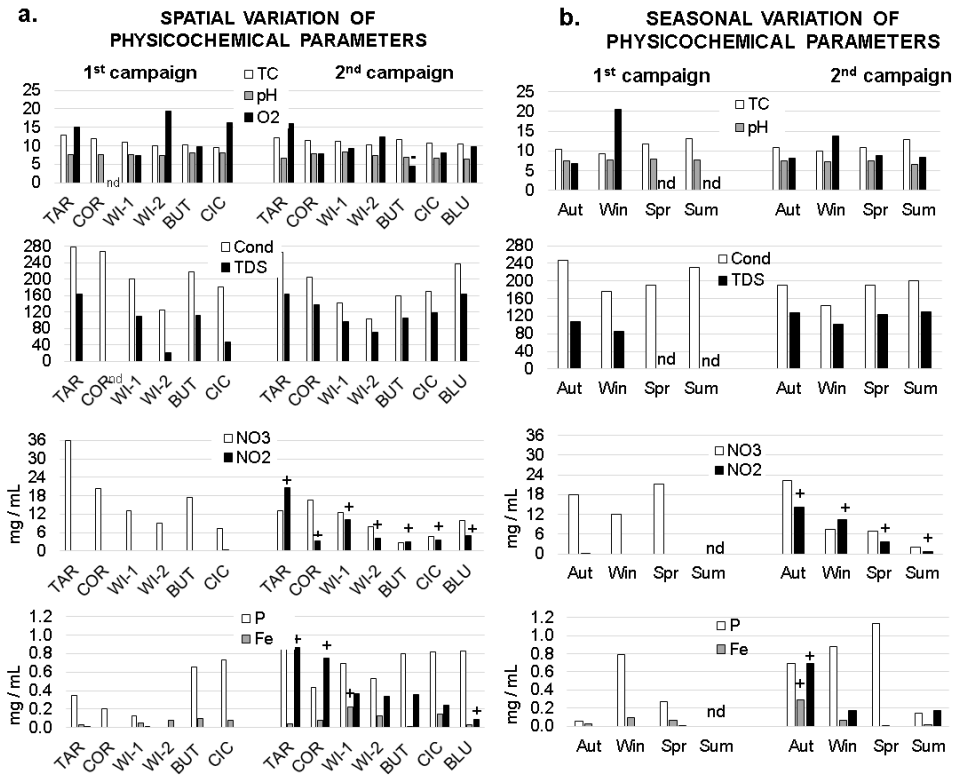

Fig. 2. Spatial variation (a) of the physical and chemical parameters, and the seasonal variation (b) in the springs of the Runcuri Plateau. TC = water temperature in Celsius degrees; pH = potential of hydrogen; O_2 = oxygen in mg/l; ORP = redox measure in mV; Cond = electrical conductivity in mS; TDS = total dissolved solids in ppt; NO_3 = nitrate; NO_2 = nitrite; $NO_3/50+NO_2/3$ = ratio of $NO_3/50+NO_2/3$; P = phosphorus; Fe = iron; NH_3 = ammonia; + = increased values over standard limits; - = decreased values under standard limits, nd = not determined.

Table 2

The physicochemical and microbiological parameters of the Runcuri Plateau springs, represented as annual average and seasonal averages. Significant differences between 1st and 2nd, detected by Student's t-test, are bold marked; nss – no statistical significance (p > 0.05); nd – not determined values

Water parameters		***Annual***		*Autumn*		*Winter*		*Spring*		*Summer*	
Sampling campaigns		***1st***	***2nd***	***1st***	***2nd***	***1st***	***2nd***	***1st***	***2nd***	***1st***	***2nd***
Physicochemical parameters											
T (°C)	*Average*	10.93	11.12	10.34	11.30	9.24	9.74	11.10	10.68	13.05	12.90
	St Dev	1.25	0.72	1.81	0.81	1.84	1.00	1.40	0.71	1.81	1.29
	P	Nss		Nss		Nss		Nss		nss	
pH	*Average*	7.71	7.18	7.50	7.44	7.70	7.31	7.88	7.44	7.76	6.67
	St Dev	0.25	0.68	0.16	0.66	0.72	0.98	0.42	0.99	0.19	0.41
	P	Nss		Nss		Nss		nss		**0.0002**	
EC (µS)	*Average*	211.25	182.68	246.17	189.67	176.50	144.00	191.33	189.86	231.0	200.43
	St Dev	57.16	56.61	78.42	64.82	90.73	63.26	49.44	63.12	56.09	49.20
	P	nss		Nss		Nss		nss		nss	
DO (mg/l)	*Average*	13.61	9.72	6.79	8.24	20.55	13.79	nd	8.83	nd	8.36
	St Dev	4.93	3.66	3.85	2.63	1.91	7.33		3.72		4.90
	P	nss		Nss		**0.05**					

Table 2 (continued)

TDS (ppm)	*Average*	90.10	122.1	108.00	128.0	84.75	101.00	nd	123.71	nd	130.57
	St Dev	56.42	35.08	56.73	41.74	57.26	43.50		30.78		33.18
	P	nss		Nss		Nss					
NO_3 (mg/l)	*Average*	17.24	9.65	18.06	22.28	12.05	7.35	21.34	7.02	nd	1.96
	St Dev	10.46	4.87	6.77	15.82	6.93	5.36	25.14	3.81		2.47
	P	nss		Nss		Nss		nss			
NO_2 (mg/l)	*Average*	0.03	7.18	0.15	14.14	0.00	10.29	0.00	3.57	nd	0.71
	St Dev	0.08	6.48	0.31	17.07	0.00	12.22	0.00	3.82		1.89
	P	**0.03**		Nss		Nss		**0.05**			
NH_3 (mg/l)	*Average*	0.00	0.43	0.00	0.69	0.00	0.17	0.01	nd	nd	Nd
	St Dev	0.01	0.28	0.00	0.53	0.00	0.08	0.02			
	P	**0.01**		**0.01**		**0.002**					
P (mg/l)	*Average*	0.35	0.71	0.06	0.69	0.79	0.88	0.27	1.13	nd	0.14
	St Dev	0.29	0.17	0.03	0.28	0.70	0.33	0.29	0.36		0.05
	P	**0.03**		**0.001**		Nss		**0.0006**			
Fe (mg/l)	*Average*	0.06	0.10	0.02	0.29	0.09	0.06	0.07	0.01	nd	0.02
	St Dev	0.04	0.08	0.04	0.33	0.10	0.07	0.04	0.02		0.03
	P	Nss		Nss		Nss		**0.02**			

Table 2 (continued)

		Microbiological parameters									
TBC (CFU /ml)	*Average*	141.86	347.39	117.75	472.33	64.60	251.00	241.83	562.29	nd	159.29
	St Dev	85.14	299.44	156.61	501.92	71.16	569.49	152.27	468.16		157.07
	P	Nss		Nss		Nss		nss			
TC (CFU /ml)	*Average*	38.14	83.18	97.25	50.00	5.60	30.43	21.17	178.57	nd	77.00
	St Dev	50.41	60.66	165.27	39.13	11.44	46.94	26.69	217.46		84.29
	P	Nss		Nss		Nss		nss			
E. coli (CFU /ml)	*Average*	8.61	11.79	6.75	15.33	5.20	22.14	8.33	11.00	nd	0.86
	St Dev	10.16	15.19	6.90	22.64	11.63	30.90	12.23	29.10		1.21
	P	Nss		Nss		Nss		nss			
Y and M (CFU/ ml)	*Average*	Nd	9.21	Nd	18.33	Nd	5.29	nd	11.43	nd	0.86
	St Dev		2.95		8.26		3.4		6.11		2.94

The Ca and Mg hardness, measured only in 1st, had annual averages of 70.74 mg/l, respectively 23.98 mg/l. These high values reflected the limestone nature of the bedrock, in which the springs are developed.

The seasonal variation of the physicochemical parameters is depicted in Figure 2b. The seasonal mean values of nitrites showed increased numbers, compared to the standard limits, in all seasons of the 2nd campaign, as well. The means of ammonia and iron concentration showed over limits only in Au-2nd.

The annual and seasonal means of the physicochemical parameters proved statistical significant differences between the two sampling campaigns (Tab. 2) in

the case of pH, dissolved oxygen, nitrites, ammonium, phosphorus and iron. The variation between seasons was also statistically significant for some physicochemical parameters (Tab. 3). Temperature, nitrates and phosphorus were the environmental factors that varied mostly between seasons.

Table 3

The statistical significances (Student's t-test) considered between the groundwater parameters from the Runcuri Plateau measured in different seasons, for each samplings campaign (1st and 2nd). Only values with $p < 0.05$ were shown in the table

Water parameters	***Sampling campaigns***	***Seasons comparations (p)***					
		Su – Au	***Au – Wi***	***W – Sp***	***Sp – Su***	***Au – Sp***	***Wi – Su***
t °C	1st	0.027					0.005
	2nd	0.027	0.009		0.002		0.0003
pH	1st	0.03					
	2nd	0.04					
DO (mg/l)	1st		0.0007				
	2nd						
NO_3 (mg/l)	1st						
	2nd	0.014	0.036		0.01	0.04	0.03
NH3(mg/l)	1st						
	2nd		0.02				
P (mg/l)	1st						
	2nd	0.0002			0.00001	0.03	0.0001
Fe (mg/l)	**1st**						
	2nd					0.04	
Ca Hardness	**1st**					0.02	
(mg/l)	**2nd**						
TBC	**1st**			0.04			
(CFU/ml)	**2nd**						
Y&M	**1st**						
(CFU/ml)	**2nd**	0.001	0.006	0.04	0.0024		0.04

Comparing between seasons, Au was distinguished from the other seasons, as the one depicting the highest statistical significance registered between the measured parameters, in different periods of year.

4.2. BIOLOGICAL PARAMETERS

Microbial content. The microbiological analysis indicated the presence of viable microbes in most of the water samples, in all springs and seasons (Tab. 2, and Fig. 3a, b). The total bacterial count in water samples was between minimum 4 CFU/ml and more than 1500 CFU/ml. The total coliforms showed individual values between 0 CFU/ml (CIC, WI-1, WI-2 in winter in 1st) and a maximum of 660 CFU/ml (TAR, in 2nd). The water samples were mostly free of *E. coli*, with individual values randomly ranging from 0 CFU/ml and 77 CFU/ml, in both sampling campaigns, in all seasons. Yeasts and molds, recorded only in 2nd, showed values between 0 CFU/ml – 33 CFU/ml, with an annual mean of 9.21 CFU/ml. No statistical differences were recorded between the sampling campaigns, because of the high dispersion of the calculated values that reflected the punctual contamination sources (Tab. 2). Considering the spatial variation of the water microbial content, the annual means showed high differences between sites and between the sampling campaigns (Fig. 3a). TAR, COR and BUT were the most contaminated springs, in both sampling campaigns.

The seasonal dynamic of the microbial content in the Runcuri Plateau groundwater (Fig. 3b) showed increased values in spring and autumn, and lower microbial concentrations in summer and winter, with the conservation of the pattern in both sampling campaigns.

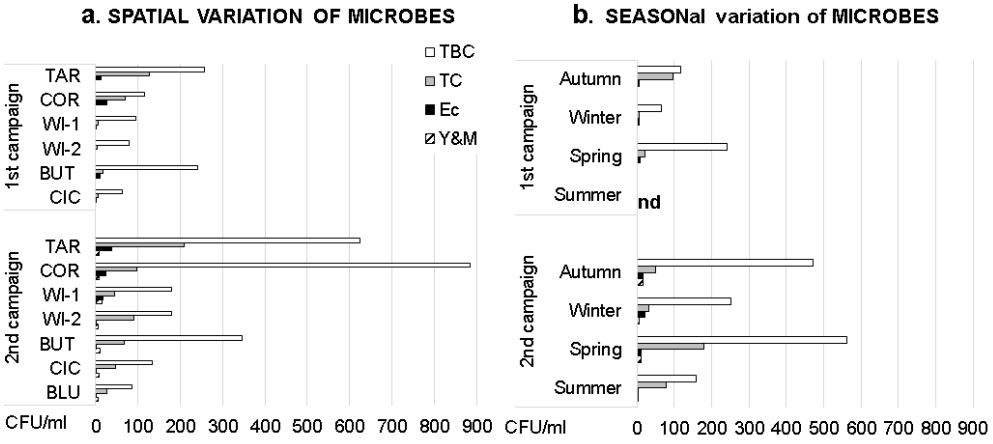

Fig. 3. Spatial (a) and seasonal (b) variation of the microbial contamination in the springs of the Runcuri Plateau: TBC = Total bacterial count in CFU/ml; Ec = *Escherichia coli* in CFU/mL; TC = total coliforms in CFU/ml; Y&M = yeast and molds in CFU/ml; nd = not determined.

Statistical differences between the sampling campaigns were registered only in Y&M group, between all seasons (Tab. 2). Although the differences between the bacterial means were high, no statistical significance were obtained, because of the high dispersion of the individual data. The variation between seasons was also statistically significant for the microbial content (Tab. 3). The yeasts and molds frequently showed a significant seasonal variation, as opposite to the bacterial content that varied significantly only once, between winter and spring.

Water invertebrates. The groundwater invertebrates showed a high difference between the two sampling campaigns, developed at five year time distance, both as taxonomic groups and as abundance of individuals (Fig. 4a). In 1st were recorded 16 taxonomic groups, excluding nauplii (Amphipoda, Bathynellacea, Cyclopoida, Harpacticoida, Ostracoda, Cladocera, Tardigrada, Acari, Oligochaeta, Nematoda, Trichoptera, Gastropoda, Bivalvia, Plecoptera, Diptera, Collembola) with a total of 1807 specimens, in contrast with 11 taxa (Amphipoda, Cyclopoida, Harpacticoida, Ostracoda, Cladocera, Acari, Oligochaeta, Tardigrada, Lepidoptera, Diptera, Collembola) with 229 specimens in 2nd.

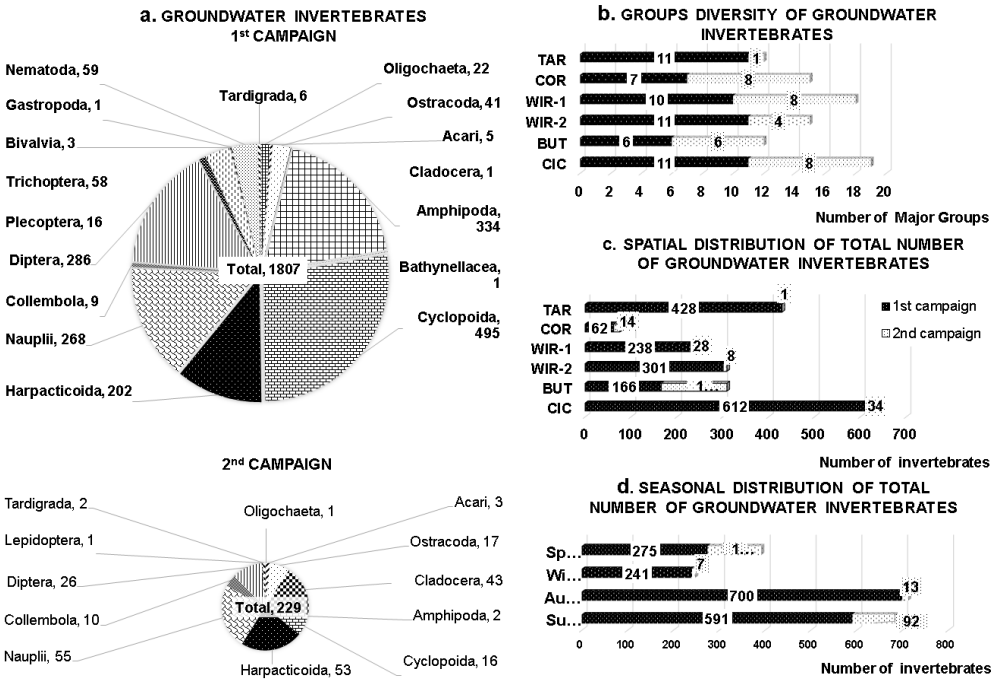

Fig. 4. Taxonomic groups of the aquatic groundwater (a), diversity of invertebrates (b), spatial (b) and seasonal (c) distributions recorded in the two sampling campaigns, in the Runcuri Plateau drinking water sources.

Under the aspect of the spatial diversity of the main taxonomic groups, CIC and WI-1 had the most invertebrate groups, including nauplii (19, respectively 18), while TAR and BUT had the less diversity (12 groups) (Fig. 4b). As total number of invertebrates, CIC site also distinguished with the high number (646 specimens), followed by TAR with a total of 429 specimens, and COR with the smaller number (76 specimens) (Fig. 4c). Seasonally, samples indicated an increased number of total invertebrates in Au and Su (713, respectively 683), and a decreased number in winter (248 invertebrates) (Fig. 4d).

5. DISCUSSION

5.1. GEOLOGY PRINT ON OBSERVED PHISYCOCHEMICAL AND BIOLOGICAL TRENDS IN RUNCURI PLATEAU SPRINGS

The geological structure of Runcuri Plateau. The geological structure of the Runcuri Plateau explains the genesis of the karstic system, its limits and connections. The relative restrain area corroborated with a good knowledge of inputs and outputs of the system enables an optimal and long term monitoring of the drinking water quality. Due to the Jurassic and the Lower Cretaceous formations, which are significant for the hydrogeological feature of the Runcuri Plateau, we discuss both levels in detail.

The *Lower Jurassic level* consists in three formations:

(a) a detrital formation that consists predominantly in red and white grainstones, sometimes with fireclay lens;

(b) a calcareous formation, 8-10 m thick, in which the Ciur Izbuc Cave and the COR spring were developed;

(c) and a marlish formation (PATRULIUS in IANOVICI *et al.* 1986).

The Middle Jurassic level has a reduced thickness, up to 10 m, and their lithology is dominated by marls and limestones. It may include levels with iron ooids, or phosphatic concretions. Both Jurassic levels together form an impermeable substratum, which has limited and conditioned the entire karstic system of the Runcuri Plateau that were built in Upper Jurassic and Lower Cretaceous limestones. The last two levels are detailed below.

The *Upper Jurassic level* is composed of the following formations:

(a) the Vad Formation, a dark grey stratified limestone, frequently showing blackish siliceous decimetric nodules, in the lower part. It is characterized by homogeneous pelmicrosparitic or pelsparitic microfacies and generally by scarce macrofauna. In the Runcuri Plateau this formation, of basal oxfordian age, has only 3-4 m in thickness (PATRULIUS in IANOVICI *et al.* 1976; COCIUBA, 2000).

(b) the Cornet Formation, a massive light grey sometimes slightly brownish limestone (50-80 m thick), characterized by sparitic microfacies with intraclasts,

bioclasts, oncoliths, and reefal constructions, in growth positions. In the basal part, encrinitic calcarenites were often noticed. The age is Oxfordian for this area, but to the north could be even Middle Tithonian (PATRULIUS in IANOVICI *et al.* 1976; COCIUBA, 2000).

(c) the Albioara Formation, a dark grey limestone, rarely with light colored interbeddings, with decimetric stratification, rarely showing metric beds, generally microsparitic, but also micritic towards the base, with large, centimetric oncolithic structure that are lighter in color. The age is Kimmeridgian-Middle Tithonian (PATRULIUS in IANOVICI *et al.* 1976; COCIUBA, 2000). In this formation two components were separated: the lower subunit is Secătura Limestone (BORDEA and BORDEA, 1987), and the upper subunit is Valea Cuţilor (COCIUBA, 2000). At the end of Middle Tithonian, the sedimentation was stopped and an under-aerial environment on a karstic plateau with lower altitude was installed. Until in Valanginian, the plateau was shaped in a typical paleotopography of a low altitude karstic plateau, with characteristic sinkholes, similar to the actual ones, from Central America. These sinkholes functioned as traps, where the bauxite was discontinuous accumulated by precipitation (BARDOSSY, 1977). The restoring of the marine sedimentation restarted only from Valanginian.

The *Lower Cretaceous level* is composed of the Blid Formation, a transgressive succession of grey, stratified, micritic, sometimes fenestral and bioclastic limestone. Discontinuous accumulations of bauxite in the basal part of this formation are also included (BARDOSSY, 1977). Two distinctive members can be easily separated in field, the Dobreşti and Coposeni Members:

(a) the Dobreşti Member is a stratified, dark grey bituminous limestone, with characeeans, ostracods and microgasteropods generated in fresh, or brackish waters with rare pyrite crystals. In the basal part, it has discontinuous accumulation of diasporic bauxites, while between the limestone beds or in the paleorelief structures sometimes breccia with red clay matrix, polychrome clays, clays or boehmitic bauxites can be identified. The total thickness has a few meters, rarely exceeding 15 m. The age is Berriasian (?) – Valanginian – Hauterivian, based on calcareous algae and foraminifera assemblages (BUCUR and COCIUBA, 1996; 1998; COCIUBA, 2000). The bitumen and pyrites contents determine an acceleration of karstic processes by oxidation due to the resulted H_2SO_4 (COCIUBA and SILVESTRU, 1989).

(b) the Coposeni Member is a thick succession, sometimes more than 300 m, of grey limestone with metrical beds, dominated by fine micritic facies, more or less fenestrated. Bioclastic-sparitic or ooidal facies are also present, in which macrofauna is mainly represented by rudists. The age, based on calcareous algae and foraminiferal assemblages, is (Late?) Hauterivian – Late Barremian (BUCUR *et al.* 1993; BUCUR and COCIUBA, 1996; COCIUBA, 1995, 2000). Different Lower Cretaceous deposits follow in other areas of the Pădurea Craiului Mountains, but strictly in the Runcuri area, the Blid formation is the last deposit.

These geological features, with large areas of karst developed, give the Runcuri Plateau the traits of a high karstic plateau.

The influence of the bedrock geology upon the drinking water quality in the Runcuri Plateau. In the Runcuri Plateau, the surface water is rapidly drained into the aquifer because of its vast network of subterranean drainage systems, such as sinkholes, fissures, galleries and caves developed in the limestone bedrock. In its way, the water acquires the salt content due to the water-rock interactions (OZYURT *et al.* 2014; LECOMTE *et al.* 2016). As a result of its bedrock geology, the geochemical signature of the Runcuri Plateau consists of high calcium and magnesium hardness, high values of conductivity, TDS, as well as of high concentrations of phosphorus, and iron. These were due to the dissolution of Mesozoic limestones (Upper Jurassic-Lower Cretacic), where calcium is found as calcite, and magnesium comes from atoms contained in the crystalline structure of calcite. Therefore, we consider that the calcium and magnesium hardness reflected the composition of the Mesozoic limestones in the studied area, and contributed to the increase of the conductivity and TDS. Because limestones are alkalizing agents for waters, the pH is generally high, despite the local factors that lead to acidification (organic pollution, chemical fertilizers, humic acids, acid rain etc). Other studies showed a similar signature in the stream waters with limestone substrate, where significant higher concentrations of Ca^{2+}, Mg^{2+}, and higher pH and conductance values were often reported, versus streams with sandstone substrate (MOSHER *et al.* 2010; MOSHER and FINDLAY, 2011).

In the Runcuri Plateau, phosphorus originated primarily from lithology, because the Middle Jurassic has phosphate concretion levels, which was reflected by BUT and BLU springs. Other concentration of phosphorous also came from the little contents of phosphorus contained within limestone. The iron concentration from the studied area came exclusively from lithology. There are ferruginous ooide levels from Middle Jurassic, and also the bauxite lens from the Jurassic-Cretacic limit that contain FeO_2 up to 25% (PATRULIUS in IANOVICI *et al.* 1976; COCIUBA, 2000).

The dissolved oxygen measured in the Runcuri Plateau springs were higher in all water sources with free flow level, TAR, WIR-2, CIC, and BLU springs. The waters that come out the surface from the porous level have less content of dissolved oxygen such as WIR-1, and BUT (Fig. 2a). The reduced oxygen levels may also be due to microbial activity which consume dissolved oxygen, as well as to oxidation processes, such as in the case of COR, where both organic pollution, and microbial content were high.

The groundwater fauna reflected the environmental conditions on a local scale, and indicated the hydrological and biogeochemical status of the groundwater ecosystems. Our finding is in agreement with several studies, suggesting that the groundwater invertebrates can be used for an ecologically based assessment of groundwater quality (THULIN and HAHN, 2008; GRAILLOT *et al.* 2014; KORBEL *et al.* 2017). Food and oxygen are key factors shaping groundwater communities, and their availability are determined by hydrological exchange with the surface environment. In the Runcuri Plateau, excluding TAR and BLU springs which originated from thick limestone layers, the other springs come from impermeable

rocks with porous-permeable interbeds, including thin layers of limestones. But all springs from the Runcuri Plateau have small collection areas, close to surface, which respond rapidly to any change from the surface. However, each spring has a different geological, hydrogeological and anthropic context, with a great variability of environmental conditions.

5.2. ANTHROPOGENIC IMPACT AFFECTING THE GROUNDWATER ECOSYSTEM

Nutrients in the groundwater of the Runcuri Plateau. Because of the human activities, the nitrogen is the most common contaminant in groundwater and therefore nitrate, nitrite, and ammonia are generally measured in aquifer systems. In unaffected shallow waters beneath forest and rangeland from USA, the background concentration of nitrates reached 2.0 mg/l (MUELLER and HELSEL, 1996). In Ireland, where a large proportion of the productive aquifers are in karstified limestone, the natural background level of nitrate was 9.2 mg/l. For this reason the nitrates concentrations that were higher than 10 mg/l were usually considered indicative of anthropogenic organic or inorganic inputs (CLABBY *et al.* 2008). Our results showed high concentrations of nitrate in the drinking water sources (Tab. 2, Fig. 2a), with one value (TAR- Sp) that exceeded the maximal limit (50 mg/l), according to the national standards for drinking water, in the 1st campaign of sampling (Tab. 1). The nitrite is an intermediate product, relatively instable, being the result of a denitrification or nitrification process, both microbial mediated. Ammonia has also a chemical instability, being detected 13 times less than nitrate, usually in very small concentrations, rarely exceeding 0.1 mg/ml in groundwater (BURKART and STONER, 2008). However, our results have shown very high concentrations of nitrites and ammonia, frequently exceeding the maximal limits (0.5 mg/l) in 2nd (Tab. 1, Fig. 2a). In the Runcuri Plateau the groundwater contamination by nitrogen was due to both the nitrogen input and the hydrologic susceptibility of soil. The principal sources of nitrogen pollution in Runcuri were represented by the wrong storage of the manure generated by livestock, and its use in agriculture as organic fertilizer, and also by the absence of any wastewater treatment system. A second source of nitrogen input can be represented by inorganic fertilizers. The hydrologic susceptibility of the thin layer of soil is due to the high solubility of limestone bedrock and to the total deforestations of the studied area.

Phosphorus is a nutrient, which even in small amount may lead to eutrophication of surface waters. In vulnerable areas, such as limestone, where the soils are shallow, the phosphate enters the groundwater and may impact in a large proportion the aquifers. The anthropic activities represented a secondary source of phosphorus in Runcuri Plateau, proven by the higher concentrations of phosphorus from the 2nd, when a higher intensity in terms of activities that might impact the water quality has been observed. CLABBY *et al.* (2008) considered 0.03 mg/l as a maximal limit of annual concentration of phosphate, in order to prevent the eutrophication in surface waters. In our samples, the phosphorus concentration exceeded this threshold level

(0.31 mg/l in 1st, respectively 0.71 mg/l in 2nd), suggesting possible future eutrophication. However, the concentration of phosphorus in the Runcuri Plateau groundwater were not a cause of concern in drinking water, because it did not exceed 2.2 mg/l the maximum accepted concentrations of phosphorus in drinking water (CLABBY *et al.* 2008).

The microbial hazard and the fauna in the groundwater of the Runcuri Plateau. Because of the karst features, the water has a minimal or no chance to be filtered and cleaned. Without sanitation systems and adequate water treatments, the drinking water sources may rapidly be pathogenically polluted and can spread waterborne diseases in the surrounding communities. Therefore, local people from less developed regions are directly exposed to risks for illnesses and diseases by consuming of the microbial contaminated waters. Even regions with functional drinking water treatment provided through the community systems can be associated with increased rates of waterborne gastrointestinal diseases, due to the rain dirty-water events (BEAUDEAU *et al.* 2014). For example, USA estimates of annual drinking water gastrointestinal cases range from 12 to 19 million people (REYNOLDS *et al.* 2008). In addition, respiratory or skin diseases can be caused by growth and release of water-based opportunistic pathogens (ASHBOLT, 2015). But in spite of their susceptibility to be contaminated, the karst springs remain crucial resources for the rural community. Because people still use the karst springs for domestic water supplies, keeping the drinking water sources safe for drinking can be a challenge for public health. The Runcuri Plateau represents a less economic developed region, with small human community that has no public sanitation system, or other water treatments implemented. Our results showed that all karst springs, used by householders in the Runcuri Plateau, were highly contaminated with bacteria including coliforms and *E.coli*, and also contained viable yeast and molds (Tab. 2 and Fig. 3 a, b). The official standards for drinking water quality in Romania (58/2002 Law) is of 0 CFU/100 ml of *Escherichia coli* and coliforms, and no abnormal modifications in the number of colonies at 37°C. These standards were not met by any water source monitored in our study. Water pathogens were grouped into two major groups. The waterborne pathogens that included enteric viruses, like fecal indicator bacteria (e.g. *Escherichia coli* and coliforms), and the water-based group that included environmental viruses, bacteria, free-living protozoa, and fungi (ASHBOLT, 2015). The drinking water sources monitored by us contained both groups, the enteric pathogens originating from the organic pollution, and the environmental microorganisms. The high microbial pollution of the studied groundwater sources was also due to the inappropriate storage of manure, and usage of it in agriculture when it is still biological active.

The springs from the plateau are characterized by a high diversity and abundance of groundwater invertebrates, but also by a high sensitivity to the organic pollution that was clearly reflected by a drastic decrease in abundance and diversity in 2nd (Fig. 4a, b, c). This was also observed by STEIN *et al.* (2010) that showed that the microbial diversity and community composition of groundwater fauna reflect impact

of agricultural activities that is indirectly displayed by the elevated nitrate concentrations. A current practice of the locals, who use the springs as drinking water, is to add quicklime in the storage part (the limnocrene part) of the springs, in order to disinfect the water. COR, WIR-1, and WIR-2 springs are sometimes treated, which leaded to an increase of pH, but also had an impact on the groundwater fauna, killing the organisms as reflected by the small number of individuals.

In fact, the microbial communities and the groundwater fauna comprise the living components of aquifers, playing together a functional role in maintaining of the ecosystem health, being responsible of groundwater purification (HERMAN *et al.* 2001; BOULTON *et al.* 2008). A health groundwater ecosystem provides high quality, stable and safe drinking water for human consumption and needs. Moreover, a healthy groundwater ecosystem may contribute to maintaining the unique biodiversity, as well as the cultural value of the rural communities through the services and the goods locals can provide (DANIELOPOL *et al.* 2008).

5.3. SPATIAL, SEASONAL AND TIME ASPECTS OF THE DRINKING WATER FEATURES

The spatial aspects of the drinking water in Runcuri Plateau. From a spatial aspect, the presence and the quality of the drinking water sources are conditioned by the lithology and the local tectonic, as well as by the anthropic activities.

TAR spring had high values of temperature, conductivity and TDS, because the water comes out to surface at the basis of a sunny slope limestone (Fig. 2a). The nutrients input and microbes content were also high due to the presence of farms in the drainage area (Fig. 3a). The number of invertebrates was high, but with few taxonomic groups observed in the samples, because of the karstic origin of water, where food resources were limited (Figs. 3b, 3c).

The COR spring crosses a limestone level of Upper Liassic and had high values of conductivity, and TDS. The nutrients and microbes were due to the organic pollution from the nearby farm (Figs. 2a, 3a). Because of the acidity caused by the organic pollution, the dissolution capacity of water increased over the natural potential. This water source had the lowest number of invertebrates because of the disinfection with quicklime made by farmers (Fig. 4c). This may be due to available food resources, given that the aquifer is very close to surface and thus having a high intake of nutrients.

Although very close to each other, due to the inclination of the layers, the surface water supply of WIR-1 and WIR-2 springs were actually different. WIR-1 collects the waters from the agricultural lands and pastures, while WIR-2 collects the waters from the forest lands, fact that explained the physicochemical and biological differences between them (Figs. 2a, 3a, 4b, c).

BUT spring was distinguished by a higher water temperature and content of microbes, due to the proximity of the surface and the sunny slopes of the water collection basin. The lowest pH corroborated with lowest nitrogen, could be explained by the lithology, rather than pollution (Figs 2a).

CIC spring showed moderate values of physicochemical parameters, rather low organic pollution, and microbial content, but the highest diversity and number of invertebrate specimens (Figs. 2a, 3a, 4b, c). The richness of invertebrates in this spring might be explained by these features, the high content of dissolved oxygen, and the superficial position of the limestone level that generates the spring.

BLU spring had the lowest microbial content, and a relative low organic pollution because of the small collection area. Because the spring collects the waters from the basis of the Upper Jurassic limestones, and has an impermeable level from Middle Jurassic with phosphate concretions, it has a relative high conductivity, TDS, and phosphorus concentration (Fig. 2a).

The seasonal aspects of the drinking water in Runcuri Plateau. It is well known that in karst the seasonal variation, along with the groundwater pathways are reflected by the environmental factors (HAHN, 2006). Our results confirmed that in the Runcuri Plateau the physicochemical factors of the groundwater were subject to seasonal variations. The water temperature was the most variable parameter within seasons (Fig. 2b, and Tab. 3), but also depended on the vegetation that covers the springs. Those situated in the forest (CIC, WI-1 and WI-2) have in general lower temperature values, compared to the springs more exposed to sunlight. Phosphorus showed high variations between seasons, part of them with statistical significance (Fig. 2b, and Tab 3). This is due to its mobilization of the geological substrate, and of the chemical fertilizers, by the rainfall and snow melting. Although the pH variations are small, the differences between Su and Au have been significant (Tab. 3). The rainfall periods from Sp and Au, as well as the melting snow led to leaches of nitrates, nitrites, ammonia, phosphorus, and iron into the groundwater, exceeding the maximal limits of national standards (Tab.1 and Fig. 2b).

The seasonal variations of the water parameters were not only the result of meteorological factors, as water temperature and precipitations regime, but were also determined by the human activities, such as agriculture and animal breading dynamics. Nitrates, phosphorus and microbial concentrations were primarily generated by the human activities and were strongly influenced by the meteorological factors. In Sp and Au the microbial contamination registered maximal values of TBC and TC, due to the overlap of two factors: the traditional fertilization with manure as organic fertilizer, and rainwater flows through manure. On the other hand, although Y & M had low concentrations, they showed a statistical significant seasonal variation (Tab. 3), being more related to meteorological factors than the human impact. Regarding the groundwater invertebrates in response to the seasonal influences, we noted as expected that autumn and summer were more favorable to sustain a rich invertebrate fauna, when the food resources are richer and more available.

The time variation of the drinking water parameters in Runcuri Plateau. Considering the time aspect, the annual means between the two sampling campaigns showed a statistical significant increase of nitrite, ammonia, and phosphorus, in the 2nd campaign of samplings (Tab. 2). Instead, a significant pH and dissolved oxygen

decrease were registered in summer and in winter respectively, in the 2nd. The microbial concentrations were higher in 2nd for all microbial groups. As the annual means, the highest contaminated springs were COR, followed by TAR and BUT, which can be explained by the pollution from the farms upstream. But the clearest effect of increasing pollution in the 2nd campaign was reflected by the invertebrate fauna (Fig. 4a), which showed a marked decrease, both in total number of specimens and group diversity, with only one exception (COR spring). The scarcity of the water sources in karst areas in general requires the use of any spring as drinking water. This is why the efforts to maintain the quality of these waters is crucial for local people. Considering the visible groundwater pollution in Runcuri Plateau, in the 2nd campaign, further monitoring and new sampling points of the main inputs and outputs of the system should be considered.

5.4. CONSIDERATIONS ON PROTECTION OF AQUIFERS AND SUSTAINABILITY OF THE RURAL COMMUNITY IN RUNCURI PLATEAU

Our study revealed the peculiarity and vulnerability of the Runcuri karst springs, exposed to anthropogenic impact that needs to be properly safeguarded. In respect of our results, the protection of the groundwater in the Runcuri Plateau can be achieved by limiting or rethinking the activities of the local communities (domestic and the agricultural) that contribute to pollution. Because the manure is still used extensively and traditionally in the whole country actually, people need to be warned about maintaining the quality of the groundwater, as source of drinking water. The people must understand what living in a sustainable way refers to. This means learning how to keep the balance between the environmental, social, and economic aspect of living, so that the sustainable management of the karst systems becomes a priority for all those that live and work in this areas, or study the karst areas (PARISE & GUNN, 2007). Knowing the characteristics of the drinking water sources, as well as the human activities that impact the karstic Plateau of Runcuri, we point out some practical ways to decrease the pollution, and to prevent the karst groundwater pollution: (1) establishing a protection perimeter for each spring with drinking water; (2) using manure and chemical fertilizers with caution to limit the contaminants runoff into the aquifers, in all area of the Runcuri Plateau; (3) properly storing manure derived from domestic animals, in constructions that prevent the leaking into the karst groundwater; (4) properly disposing of the domestic sewage in septic systems, avoiding the discharge directly into sinkholes; (5) an adequate garbage management, by pickup program sustained by the local authorities; (6) maintaining the forests and limiting the overgrazing will prevent the epikarst destruction, and the soil erosion; and (7) initiation of a program of continuous surveillance and control of the quality of drinking water sources, at least twice a year, in autumn and spring, by monitoring the nitrogen and the microbial content.

6. CONCLUSIONS

The good knowledge of the geology of the Runcuri Plateau allowed us to understand why the physicochemical and biological features of the water sources are so different, even at the very close springs.

In the Runcuri Plateau the anthropogenic pollution was remarked and highlighted by the following parameters: ammonium, nitrite, nitrate, phosphate and faecal coliforms including *E.coli*. These reflected the vulnerable nature of the drinking water sources at the geological marginal limits of the plateau. The aquatic fauna responded to the organic pollution by a pronounced decrease in diversity and abundance, therefore, we conclude that the invertebrates we collected from springs can be considered a good indicator for water pollution.

The quality of drinking water sources from the Runcuri Plateau were subject to geological substrate, anthropic actions, seasonal and time variations. Taking into account these constraints, specific protective measures can be considered in order to maintain the water quality of the springs used by the inhabitants of the Runcuri Plateau.

Given the high fluctuation of the physicochemical and biological parameters showed by the preliminary data of this study, we consider necessary to continue the monitoring of the Runcuri Plateau springs and to extend the sampling area to the final output of the system.

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[1] *"Emil Racoviţă" Institute of Speleology, Clinicilor 5, 400006 Cluj-Napoca, Romania, E-mail: daniela.borda@academia-cj.ro*

[2] *"Emil Racoviţă" Institute of Speleology, Calea 13 Septembrie 13, Sector 5, 050711 Bucharest, Romania E-mail: ioana.meleg@gmail.com*

[3] *Geological Institute of Romania, Caransebeş 1, Sector 1, Bucharest, Romania E-mail: ioan_cociuba@yahoo.com*