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DATA ON THE HYDROGEOGRAPHICAL CONDITIONS OF BARADLA CAVE: SEEPAGE AND DRIP WATERS

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Summary: This paper analyses the hydrological features of Baradla Cave. Together with the Slovakian caves the Baradla-Domica cave system is a UNESCO world heritage site and the preservation of karst water, as a drinking water reservoir is a very important task. First of all, the water balance (precipitation, infiltration water, seepage water and evapotranspiration water) of the catchment area was defined. Secondly, the changes in different physicochemical parameters (water temperature, pH, electric conductivity, dissolved oxygen content, redox potential and nitrate concentration) of karst water were defined by using stable and mobile monitoring sites after the rapid and slow melting of snow. The quality (chemical parameters) of dripping water was also examined during these periods. We found that the extreme water level fluctuations imply changes in water quality parameters that affect drinking water quality. Further monitoring would be particularly important since it provides an opportunity to understand the changes in trends and thus the future development of a more accurate protection strategy for the catchment area.

Key words: karst hydrogeography, karst water balance and quality, Baradla Cave, Hungary

1. INTRODUCTION

The Baradla-Domica Cave complex is a UNESCO world heritage site and it is under the protection of the Ramsar Convention. The cave system is located in the Hungarian-Slovakian borderland, in the Gömör-Torna Karst which is a geographically homogeneous region extending over 60.000 hectares. The area is divided into the Slovak Karst (northern part) and the Aggtelek Karst (southern part) areas that host more than 700 caves. The underground drainage system and most of the caves in the karst region were formed in the Middle and Upper Triassic limestones of the Silica Nappe since this type of bedrock is eminently prone to karstification. Limestones occur together with sandstones and shale pala. The cave system is a typical example of multi-level speleogenesis. Under the main passage two lower caves (Long Lower Baradla Cave and Short Lower Baradla Cave) evolve independently from each other.

The hydrogeographical study of the cave is of particular importance concerning the public water supply of the nearby villages. This paper presents some data provided by the hydrochemical monitoring that was started in 1980 and has been continuous since 2000 with the aim of analyzing the changes of seepage and infiltration waters.

2. MATERIALS AND METHODS

GIS and field data processing was based on the hydrological model of the cave. The analyses of infiltration water were carried out by using an YSI multiparameter water quality monitoring system. YSI probes were installed in the Styx and Acheron streams and water temperature, pH, electric conductivity, dissolved oxygen content, redox potential and nitrate concentration were measured continuously. Occasionally spot investigations were carried out. Drip water samples were collected in 500ml bottles and were analysed on the surface by an YSI device. The obtained data were evaluated by GIS methods.

3. REASULTS AND DISCUSSION

The Aggtelek Plateau is connected to the southern limestone belt of Silice Plateau. In the north erosion valleys separate the mountain tops dissected by low altitude dry doline valleys from the southern part of Silica Nappe. The southern boundary of Aggtelek Plateau is the covered karst area of Putnok Hill. In the east the Hideg Valley separates the limestone bed from the Galyaság. Different doline generations can be identified on the karst plateau. On the contrary, on the karstic tops and interfluves only a few dolines can be found. Dolines have transformed into uvalas on the catchment areas of Béke and Baradla caves and in Hideg Valley.

To the west Aggtelek Karst is adjacent to the covered karst area. The gravel covered hilly landscape, which is fragmented by erosional and derasional valleys, is drained by the tributaries of Sajó. A 300-400 metres high, gravel-covered watershed rises 1-2 kilometres from the karstic range. From its flat crests waters flow on the one hand towards the west, towards the tributary valleys of Sajó Valley and on the other towards the karst area, where they disappear in edge sinkholes. The water of these sinkholes reappears in Jósva Stream and flows into Bódva Stream. All surface streams between the edge polje of Hosszúszó and the sinkhole of Béke Cave in Nagy Valley enter sinkholes and go through the underground karst system. Under the tops of Aggtelek Plateau the sinking stream system of Baradla-Domica conducts the waters to Jósva springs. The most distant swallet of the spring is the Ördög Hole 343 metres above sea level. The temporary stream originating at the southern edge of Silica Plateau disappears in the large opening of a sinkhole at the limestone bed of Aggtelek Plateau. Here begin the paths of the underground Styx Brook that formed the main passage of Domica Cave by its corrosive and erosive activities. The underground stream is enriched by the waters coming from the other sinkholes situated on the edge of the karst plateau.

Water bodies accumulating under Baradla Top are from a 7 km^2 area. The three most mature sinkholes open up here: the Bába Hole, the Acheron and the Little Baradla swallets. Bába Hole was formed at the confluence of the longest valley having the highest water transport capacity. Tracing tests showed that water from this sinkhole flows via the Long Lower Baradla Cave and appears in one of the Jósva springs, in Medence Spring (Szilágyi 1982). A 1 metre high watershed is situated between Bába Hole and Acheron Sinkhole and therefore water goes to the Acheron Sinkhole during floods. This nourishes the Acheron Brook of Baradla Cave that flows into the Styx at the labyrinth of the Aggtelek entrance area. As the Acheron Sinkhole is not able to swallow large amounts of water,

water runs toward Little Baradla sinkhole which is capable of draining it. These three sinkholes together with the Slovakian Ördög Hole provide most of the water supply of Baradla Cave. Zsombor Hole belongs to the system Lower Baradla Cave. However, it feeds the Lower Baradla Cave at low water level while at times of high water level water flowing into Zsombor Hole also goes to Vörös Branch, which is a side branch of Retek Branch.

The confluent Styx and Acheron Streams no longer flow through the main passages of Baradla Cave, as the level of springs has moved deeper. The stream does not get further than Vaskapu Strait at low and middle water, since water departs to the mainly unknown passages of Lower Caves by different sinkholes (Szilágyi 1982). Nowadays, water runs through the middle level of the cave and reaches the main sinkhole only when high floods occur. Runoff water disappearing in the swallets inside the cave appears in Jósva springs that consist of three independent springs: Táró, Cső and Medence springs. Sinkholes of the Long Lower Baradla Cave constantly provide water to the Lower Cave which appears later on in the Medence Spring. This water originates from the infiltration water of the sinkholes, seepage karst water, groundwater and water from deep reservoirs. The water supply of the Short Lower Cave comes from the large sinkhole situated in the Giant's Hall and reaches the surface at the Táró Spring. The above mentioned two springs are next to each other and were separated from each other by the construction of engineering structures after the great flood in 1955. Although both springs indicate flooding within a few hours, flood reaches the springs at different times (Szilágyi 1982). Side passages join to the main level passage of Baradla Cave that has been continuously developing since the beginning of the Pleistocene (Vid 1988). The hydrogeological system of Domica-Baradla also includes Nagy-Ravasz Hole.

3.1. The hydrological features of Jósva springs

Jósva springs are a group of three springs that are located very close to each other. Medence Spring has the highest discharge whereas Cső Spring is characterized by the lowest level of water flow. The water of these springs originates from the Long Lower Cave while the Táró Spring is fed by the Short Lower Cave. The water regime of the latter spring is characterized by extreme changes. These springs are classic examples of shallow karst springs that are supplied by precipitation. As the residence time of water is very low, it shortly appears on the surface. The quality and quantity of water at the springs fluctuates significantly reflecting the changes of precipitation. The hydrological cycle of Jósva springs is characterized by floods occurring at the end of winter, early spring, spring and early summer (Fig. 1). As a result, the chemical parameters of water fluctuate immoderately, as well (Table 1).

Table 1 Physicochemical parameters of Jósva springs between 2000 and 2001

Date	°C	pH	T.C	Alk.	K	Ca	Mg	Fe	Mn	NH_4	Cl	SO_4	HCO_3	NO_3	NO_2
04.04.2000	10.6	7.21	174	6.0	1.9	110.0	8.7	0.04	0.02	0.31	6.5	18.2	366	4.8	0.01
06.15.2000	11.7	7.70	202	6.7	1.0	129.0	11.2	0.04	0.02	0.07	*11.5*	18.9	409	*7.5*	0.01
08.09.2000	12.1	7.96	197	6.8	1.0	133.0	7.6	*0.38*	0.36	0.01	*11.5*	19.1	412	4.8	0.01
10.02.2000	14.1	7.22	174	5.8	1.7	108.0	11.0	0.04	0.02	0.02	7.5	19.2	354	*11.1*	0.01
12.13.2000	13.2	7.82	165	5.6	1.9	99.4	12.6	0.05	0.02	0.11	10.0	19.2	343	*11.2*	0.01
02.05.2001	11.7	7.47	175	5.9	2.0	116.0	7.2	0.04	0.00	0.01	6.5	38.4	357	*8.4*	0.01
04.17.2001	12.2	7.29	191	6.1	1.8	124.0	7.7	0.06	0.00	0.00	7.5	36.0	372	*7.9*	0.01
06.11.2001	13.7	7.60	193	6.0	1.9	113.0	15.2	0.00	0.00	0.17	7.0	36.0	366	*10.3*	0.01
08.06.2001	13.1	7.62	185	6.2	1.9	103.0	18.1	0.00	0.00	0.15	*10.0*	24.0	378	*11.4*	0.01
10.04.2001	14.3	7.29	186	5.9	1.9	106.0	16.5	*0.12*	0.29	0.32	7.5	16.8	357	*12.1*	0.02
12.10.2001	12.5	7.70	171	5.8	1.7	105.0	10.4	*0.11*	0.07	0.04	9.0	16.8	354	*14.1*	0.00

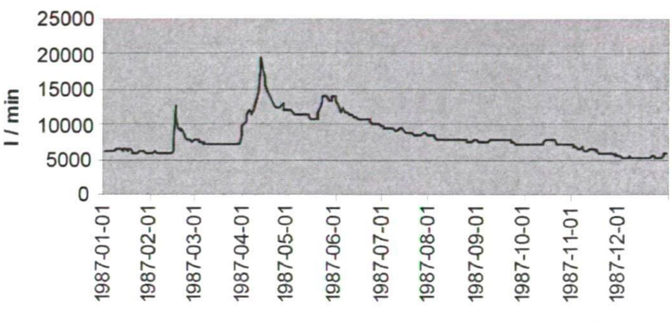

Fig. 1 The changes of discharge of Jósva springs in 1987 (VITUKI)

Table 2 Average annual precipitation on the catchment area of Baradla Cave for 10 years

Weather Station	Mesurement frequency	Multi-annual rainfall (mm)
Aggtelek	daily	701.00
Bagolyvágás	monthly	631.00
Nagy Valley	monthly	578.00
Jósvafő	daily	657.00
Total Average		641.75

In Baradla Cave the Long Lower Cave and the Short Lower Cave take the most of the water. The average discharge of Táró Spring is 300 l/min, however the estimated discharge can reach 1 000 000 l/min in case of floods. The joint discharge of Cső and Medence springs is approximately 10 000 l/min while it rises to 200 000 l/min when floods occur. Owing to the fact that the springs are too close to each other their water flow measurement could not be solved separately and therefore the total discharge was recorded. The multi-annual discharge of Jósva springs is 14 364 m^3/d.

The total annual discharge of the karst springs is equivalent to the annual infiltration on a karstic area. The same applies to the values of the average multi-annual infiltration. The percentage of average multi-annual infiltration can be calculated by using the average multi-annual water flow and the average multi-annual precipitation.

The sum of the *average multi-annual water flow* ($\overline{Q}$) was determined by multiplying the daily water flow by 365:

$$\overline{Q} = 14\,364 \cdot 365 = 5\,242\,860\,(\mathrm{m}^3) \tag{1}$$

If the *average multi-annual precipitation* ($\overline{C}$) is multiplied by the surface area of the drainage basin we get the average multi-annual precipitation for the catchment area in m^3. The total area of the investigated karstic and non-karstic drainage basins is 29.83km^2 (29 830 000 m^2). The *average multi-annual precipitation* for this catchment area is:

$$\overline{C} = 29\,830\,000 \cdot 0.642 = 19\,150\,860\,(\mathrm{m}^3) \tag{2}$$

where 0.642 is the *average multi-annual rainfall* in metres. In the light of the above the *average multi-annual infiltration* (*B*) is calculated as follows:

$$\overline{B} = \frac{14\,364}{0.642 \cdot 29\,830\,000} \cdot 100 = 27.37 \approx 27\% \tag{3}$$

This means that the value of the average multi-annual infiltrating precipitation is 173 mm. The determination of the *average multi-annual surface runoff* is required for the above. By establishing a runoff register parcel at Jósvafő weather station we found that surface runoff occurs only in case of heavy rainfalls. Due to their scarcity, the average multi-annual surface runoff usually does not exceed the 2% of precipitation. Since the average slope of the experimental plot corresponds to the average slope of the catchment area, the calculated value is acceptable for the drainage basin of Baradla Cave.

As a result, it can be concluded that the level of the *average multi-annual evapotranspiration* is the 71% of the average multi-annual rainfall (456 mm) in case of 27% infiltration and 2% surface runoff (Table 3). This result matches the outcome of water balance calculations done for both the other areas of Aggtelek Karst, and the karstic area as a whole.

Table 3 The water balance of the catchment area belonging to Baradla Cave

Average multi-annual							
Total precipitation		Infiltration		Surface runoff		Evapotranspiration	
mm	%	mm	%	mm	%	mm	%
642	100	173	27	13	2	456	71

3.2. The analyses of seepage water in Baradla Cave

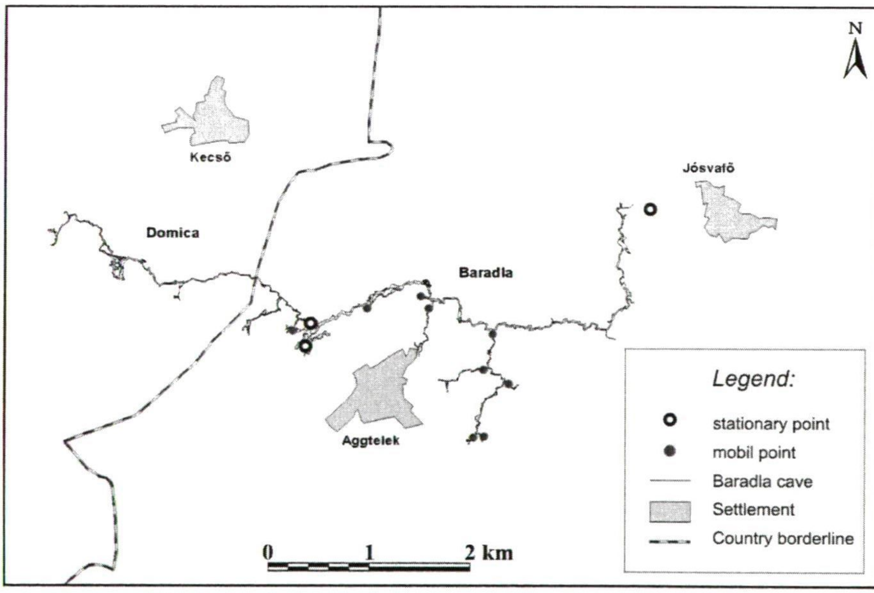

Fig. 2 The location of monitoring stations in Baradla Cave

The water quality of infiltration water is significantly modified by the human intervention and by the vegetation and soil cover of the karst area. As the soil and vegetation cover binds certain substances (e.g. heavy metals) it can change the quality of infiltration water. Seepage water flows directly into the system and therefore can bring harmful substances to the aquifer that restricts the use of the spring as public drinking water supply. A number of researches have dealt with the chemical and hydrological analysis of the cave and the springs (Dudich 1930, Kessler 1955, Jakucs 1960, Sásdi 1992, Stieber 1995, Maucha 1998, Szőke and Keveiné Bárány 2003, Gruber 2004, Gruber 2006). These studies have shown that sometimes contaminants get into the system, which deteriorate its water quality (Szőke and Keveiné Bárány 2003). Consequently, regular monitoring is required. Measurement points were installed in the spring zone in order to study the accumulation and elimination of the various contaminants. Continuous monitoring immediately filters contaminants (e.g. agricultural pollutants) after the onset of flooding. Mobile measurement points had to be installed in order to find the sources of additional pollution (Fig. 2).

Changes in the water chemistry of Acheron Stream linked to the typical regime of the cave are different concerning stagnant flow, slow water flow and sudden flooding (Figs. 3-6).

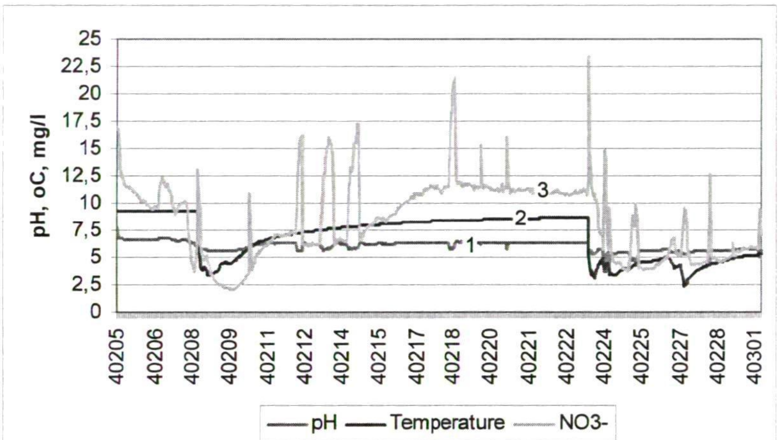

Fig. 3 Acheron Stream, slow melting of snow (February 2004)
1 = pH; 2 = temperature; 3 = NO_3^-

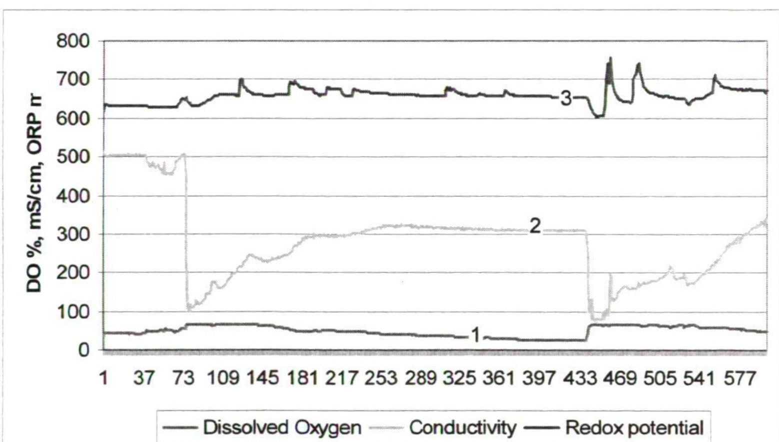

Fig. 4 Acheron Stream, slow melting of snow (February 2004)
1 = dissolved oxygen; 2 = conductivity; 3 = redox potential

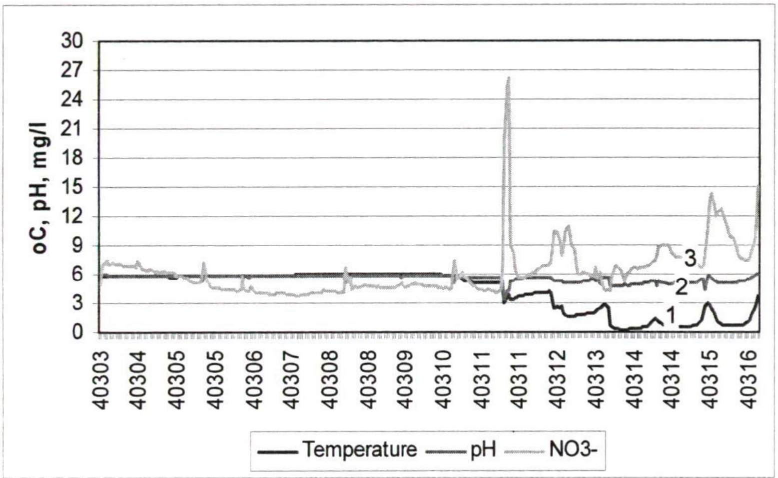

Fig. 5 Acheron Stream, flooding after sudden snowmelt (March 2004)
1 = pH; 2 = temperature; 3 = NO_3^-

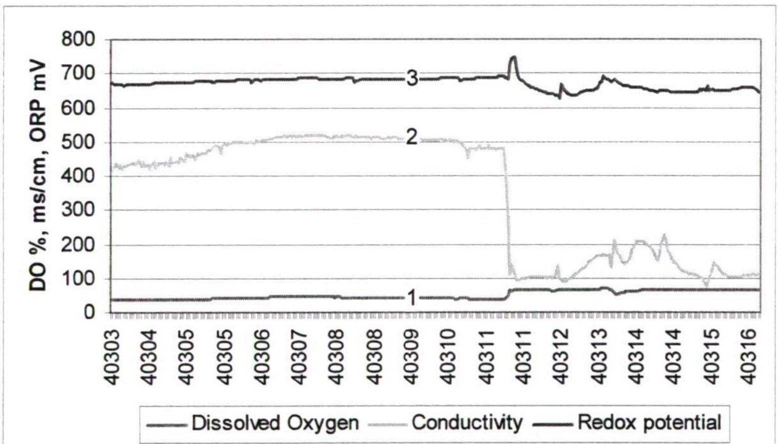

Fig. 6 Acheron Stream, slow melting of snow (March 2004)
1 = dissolved oxygen; 2 = conductivity; 3 = redox potential

As a result of snowmelts due to the rise in air temperature flood waves go through the creek with daily intensity. After the start of snowmelt the dissolved oxygen content of water rises immediately with the first shockwave. Electric conductivity, which usually changes similarly to water temperature, drops suddenly in case of floods. At the time of intense inflow, pH decreases suddenly sometimes even with a two-value-change. Although redox potential increases first, it decreases equally sharply when the intensive inflow stops. The nitrate content of the water rises significantly when infiltration starts and decreases gradually later on. When the amount of inflow lessens a progressive warning of the stream begins. As the flow ceases lakes form in pool-like depressions. Water temperature becomes constant at around 8.8°C. The dissolved oxygen content of water stagnates first and then starts to decrease slowly. pH stabilizes around 7.8 with small fluctuations. Redox potential rises a little bit while the electric conductivity declines. Nitrate concentration steadily decreases due to the different chemical reactions.

3.3. Drip waters

The first drip water samples were collected in January 2009 (Table 4) as a number of dripping points became active after the start of snowmelt. Drip waters were grouped on the basis of their temperature as follows: 8-9°C, 9-10°C and above 10°C. In the case of the first group the solution did not warm up, since the infiltration of rainwater was relatively fast due to the smaller thickness of the host rock and its tectonic features. The second group consists of water with normal infiltration conditions and the ones with extremely low infiltration conditions belong to the third one.

Table 4 Chemical parameters of drip waters (January 2009)

Place	Temp. (°C)	Conductivity (mS/cm^2)	Dissolved ox. (%)	pH	Redox. pot. (mV)	NO_3 (mg/l)
1. Pitvar	10.09	246.0	21.0	9.530	20.10	0.095
2. Acheron room.	9.58	244.0	38.5	9.550	29.40	0.551
3. Róka branch 1	9.80	269.0	10.4	9.450	8.70	0.115
4. Róka branch 2	9.82	287.7	40.5	9.240	117.40	0.014
5. Róka branch 3	9.91	295.9	39.0	9.020	191.10	0.512
6. Kerülő	9.65	289.1	7.2	9.270	94.50	0.155
7. Fekete room.	10.20	285.4	1.1	9.240	66.10	0.025
8. Denevér 1	10.28	294.2	2.8	9.225	72.20	0.655
9. Denevér 2	10.72	339.2	3.8	9.240	76.10	0.547
10. Fekete-t.	10.37	300.1	23.0	10.190	90.10	0.698
11. Danca	11.04	309.2	3.5	9.520	88.60	0.547
12. Törökfürdő	8.66	209.6	17.8	9.480	85.20	0.254
13. Lelák	8.65	210.6	20.6	9.480	86.60	0.965
14. Viasz-u.	9.20	309.8	28.2	9.320	90.30	0.589
15. Morea	9.88	342.0	28.7	9.200	98.30	0.547
16. Gát	9.76	319.0	9.6	9.390	56.70	0.855
17. Csipke-t.	0.70	271.2	46.3	8.980	48.70	0.559
18. Libanon	9.85	220.7	13.7	9.240	88.70	0.115
19. Nehéz-út	9.74	398.5	5.8	9.010	106.10	0.556
20. Vaskapu	9.24	305.1	24.9	9.120	108.40	0.225
21. Törökmecset	9.37	297.0	6.5	9.080	187.10	0.654
22. Szemiramisz	9.28	323.7	39.2	9.160	147.10	0.569
23. 2350 m	9.27	347.1	5.5	8.950	142.90	0.478
24. Matyórojt	9.31	232.6	61.2	9.190	130.40	0.522
25. Csikóstanya	9.35	328.5	13.6	9.010	128.20	0.125
26. Dareiosz	9.30	243.7	46.3	9.120	88.54	0.154
27. Retek branch	8.40	102.4	13.9	9.120	94.40	0.569
28. Anyósnyelv	8.15	270.2	21.7	8.940	107.10	0,488
29. Minerva	9.32	304.6	57.7	8.850	116.20	0.965
28. 4500 m	9.15	275.4	73.6	8.950	116.70	0.441
29. 4600 m	8.82	309.1	44.0	8.850	125.10	0.468
30. 4700 m	8.70	354.4	21.4	8.640	147.10	0.977
31. Vörös Lake	9.24	345.2	25.1	8.750	147.30	0.425

Besides, other chemical parameters were also analysed (Table 4). The redox potential, the electric conductivity and the nitrate concentration of drip waters were lower in January than in April (Table 5) while the pH values and the dissolved oxygen content of the water changed reversely. It means that waters infiltrating after the melting of snow bring more inorganic material into the system and thus the specific electric conductivity rises significantly. While concerning Jósva springs some waters were found to be above the tolerable limit of clean water for NO_3^-, dripping water samples never exceeded this limit. pH values differed significantly as the pH of Jósva springs were one order of magnitude lower than the pH of dripping water samples. The changes of pH, redox potential and nitrate concentration imply the attenuation of infiltration water. It can also be concluded that contaminations reach the system mostly due to rapid floods.

Table 5 Chemical parameters of drip water (April 2009)

Place	Temp. (°C)	Conductivity (mS/cm^2)	Dissolved ox. (%)	pH	Redox. pot. (mV)	NO_3 (mg/l)
1. Pitvar	10.04	754	13.90	8.54	188.2	1.563
2. Acheron room	10.58	749	26.25	8.65	175.4	1.554
3. Mórea	10.48	757	1.40	8.54	185.5	3.565
4. Libanon	9.45	978	7.60	8.94	193.2	2.264
5. Vaskapu	10.04	965	9.90	8.34	195.9	1.025
6. Törökmecset	9.39	712	11.20	8.09	192.7	1.463
7. Matyórojt	9.86	932	16.90	8.08	196.4	1.745
8. Csikóstanya	9.75	942	15.90	8.94	207.6	1.519
9. Dareiosz	9.24	549	22.90	8.11	194.2	1.375
10. Retek branch	8.97	1078	14.00	8.96	206.9	2.841
11. Anyósnyelv	8.62	894	18.50	8.21	202.9	1.446
12. Minerva	9.67	1033	18.30	8.02	206.2	2.157
13. 4500 m	9.56	1123	31.20	8.98	208.1	1.111
14. 4600 m	8.62	797	28.30	8.87	203.2	2.381
15. 4700 m	8.85	756	33.40	8.14	202.3	0.740

4. CONCLUSIONS

The water balance for the catchment area of Baradla Cave was determined. It can be concluded that from the average multi-annual precipitation (642 mm) 27% (173 mm) infiltrates into the cave, 2% (13 mm) runs off the surface and 71% (456 mm) enters the atmosphere by evapotranspiration. The hydrogeochemical characteristics of Jósva springs and the dripping waters were analysed separately. The flow rate and the water quality of the springs fluctuate significantly in correspondence with the changes of precipitation. The delay of precipitation is short in the aquifer. The hydrological cycle of Jósva springs is characterized by floods occurring at the end of winter, early spring, spring and early summer.

The infiltration waters of Baradla Cave were listed in three groups based on their temperature. The temperature of these percolation waters were primarily defined by the lithological structure and the thickness of the host rock above. The chemical indicators were evaluated by comparing the samples collected in January and April. Redox potential, nitrate levels and electric conductivity were lower while the pH and the dissolved oxygen content of water was characterized by higher levels in January than in April. This means that waters infiltrating after the melting of snow bring more inorganic material into the system and thus the specific electric conductivity rises significantly. Further monitoring would allow the better understanding of changes in trends and the development of a more accurate drainage basin protection.

REFERENCES

Dudich E (1930) Az Aggteleki barlang vizeiről. [About waters of Aggtelek Cave. (in Hungarian)] Hidrológiai Közlöny 1:1-33

Gruber P (2004) A Baradla-barlang hidrológiai észlelő (monitoring) rendszerének bemutatása. [Presentation of hirdrological monitoring system of Baradla Cave. (in Hungarian)] Karsztfejlődés 9:339-347

Gruber P (2006) A Baradla-barlang környezeti monitoring rendszerének bemutatása és az eredmények értékelése. [The environmental monitoring system of Baradla Cave and the evaluation of its results. (in Hungarian)] Barlangkutatók szakmai találkozója. Szeged. CD.

Jakucs L (1960) Az Aggteleki barlangok genetikája a komplex forrásvizsgálatok tükrében. [Genetic studies of caves in Aggtelek in the light of complex investigation of springs. (in Hungarian)] Karszt és Barlangkutatás 1959. 1:37-77

Kessler H (1955) Forrástani részletvizsgálatok az Aggteleki karsztvidéken. [Partial investigation of springs on Aggtelek Karst. (in Hungarian)] VITUKI beszámoló 1954. 134

Maucha L (1998) Az Aggteleki-hegység karszthidrológiai kutatási eredményei és zavartalan hidrológiai adatsorai. 1958-1993. [Results and undisturbed data of karsthydrological researches on Aggtelek Hills. (in Hungarian)] VITUKI Rt. Hidrológiai kiadványa. 414

Sásdi L (1992) Az Aggtelek-Rudabányai-hegység vízrajzi és vízföldtani viszonyai. [Hydrological and hydrogeological relationships of Aggtelek-Rudabánya Mountains. (in Hungarian)] Manuscript. Aggteleki Nemzeti Park. 1-101

Stieber J (1995) Barlangklimatológiai és vízkémiai szakértői vélemény a Baradla-barlang aggteleki szakaszának gyógy-barlanggá nyilvánításához. [The climatological and water chemical expertise of the Aggtelek section of Baradla Cave, done for its enlistment as a medical cave. (in Hungarian)] Manuscript. Aggteleki Nemzeti Park. 16-21

Szilágyi F (1982) A Baradla Rövid-Alsó-barlangjának feltárása. [The exploration of Short Lower Baradla Cave. (in Hungarian)] Karszt és Barlang 2:67

Szőke E, Keveiné Bárány I (2003) Karsztvíz vizsgálatok az aggteleki karszton, különös tekintettel a nehézfém szennyezésre. [Karstwater investigations on Aggtelek Karst with special regard to contamination of heavy metal. (in Hungarian)] Karsztfejlődés 8:173-185

Vid Ö (1988) A Baradla-barlang hossza. [The length of Baradla Cave. (in Hungarian)] Karszt és Barlang 1:61

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