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Thermomineral water of Nikoličevo Spa (eastern Serbia)

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Abstract. New monitoring results (2000–2002) of the thermomineral water outflow and quality regime of the Nikoličevo Spa (eastern Serbia) show that, during 30 years, a scaling process occurred and decreased the well outflow by app. 80%, as a consequence of well deterioration and reservoir depletion. Consequently (slower water movement), the water temperature increased by 1,5–2° C. Stabile values of the outflow and water quality parameters, registered during new monitoring, show an insignificant influence of the annual meteorological cycle on the outflow and quality regime. According to its chemical composition, the water is sodium-bicarbonate- fluoride, oligomineral and isothermal and a wide spectrum of applications is available. The limit for an efficient exploitation and application of the water is the current low outflow rate, so the drilling of new wells is recommended.

Key words: thermomineral water, Nikoličevo Spa, scaling, annual outflow regime, quality.

Апстракт. Резултати новог (2000.–2002. год.) мониторинга режима истицања и квалитета термоминералне воде Николичевске бање (Источна Србија) показују да је, током периода од 30 година, издашност бунара опала за око 80 %, највероватније као последица “старења” бунара и делимичне исцрпљености термалног резервоара. Последично (због успореније водозамене), температура вода повишена је за 1,5–2° C. Стабилне величине издашности и параметара квалитета вода, регистроване током нових испитивања, указују да не постоји осетан утицај годишњег метеоролошког циклуса на режим издашности и квалитета. Према хемијском саставу вода Николичевске бање се сврстава у натријум-хидрокарбонатне флуоридне олигоминералне изотерме, са широким спектром могућности коришћења. Лимит за ефикасно коришћење ове воде представља тренутна издашност, па треба приступити изради нових бунара.

Кључне речи: термоминерална вода, Николичевска бања, пад издашности, годишњи режим издашности, квалитет.

Introduction

There is a natural occurrence of thermomineral water in the village Nikoličevo, in eastern Serbia, within the “Timok eruptive region”, app. 7–8 km north–east of the town of Zaječar. The thermomineral waters of the Timok region have been known and used for spa treatments since the Roman times. Another 4 occurrences of thermomineral waters are known in the region: Brestovac Spa, Gamzigrad Spa, Šarbanovac Spa and Sumrakovac Spa, all of them being related to the deep faults of a NW–SE general strike. In the seventies of the 20th century, an extraordinary outflow and quality of thermomineral water of the Nikoličevo Spa were stated by drilling holes. Unfortunately, during almost thirty years, there was no real (economic) interest in this hydrogeological phenomenon. During the period 2000–2002 a certain scope of explorations was realized: monitoring of the annual outflow and quality regime in order to define exploitable water reserves.

Geology

The geological structure of the Nikoličevo Zone is comprised of Barremian–Aptian carbonate forms, flysh, volcanoclastic and volcanic rocks of Upper Cretaceous age and younger Miocene and Quaternary deposits (Fig. 1). The Barremian–Aptian ($K_1^{3,4}$) limestones are developed according to the “Urgonian facies” type, which

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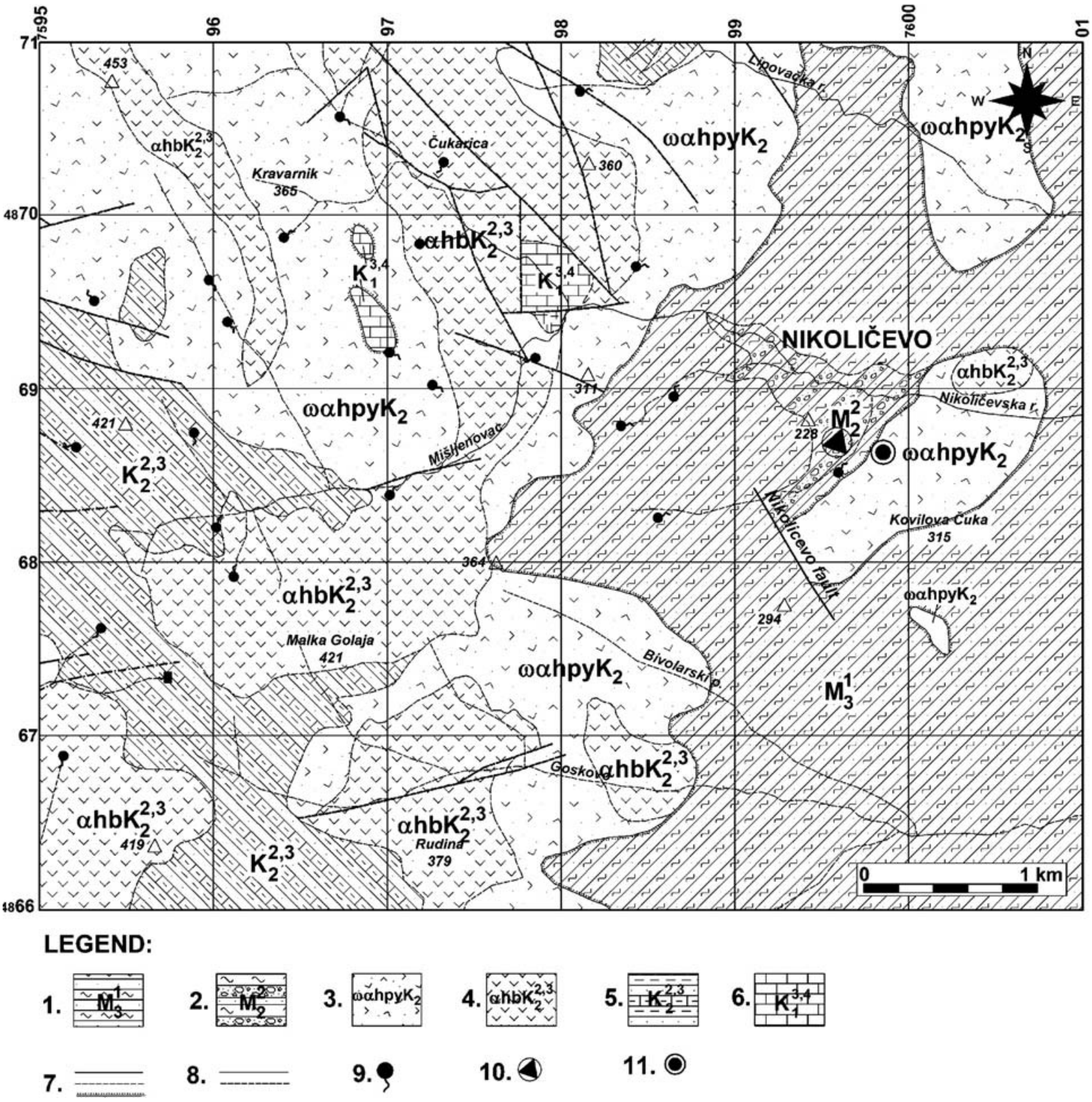

Fig. 1 Hydrogeological map of the Nikoličevo wider zone (after VESELINOVIĆ 1967, simplified). Legend: 1. Miocene sandstones and sandy clays (Intergranular aquifer); 2. Miocene conglomerate, clays, and sands (Intergranular aquifer); 3. Turonian– –Senonian volcanoclastites-agglomerate, breccias, tuff and sandstone (Fissured aquifer); 4. Turonian–Senonian andesites (Fissured aquifer); 5. Turonian–Senonian sandstones, marlstones, marl carbonates (Minor fissured aquifer); 6. Barremian–Aptian limestones (Karst aquifer); 7. Geological contacts; 8. Faults; 9. Spring; 10. Group of thermomineral springs; 11. Group of (B1 and B2) wells.

are supposed to be the outermost northern outcrops of the complex Tupižnica–Knjaževac synclinal. Within the vast and, as to geologic structure, compound Turonian– –Senonian volcano-sedimentary complex, there can be singled out: flysch ($K_2^{2,3}$) sediments (sandstone, marlstone, marl carbonate) lying transgressively over Urgonian carbonates; volcanoclastites ($\omega\alpha hpyK_2^{2,3}$) represented by agglomerate, breccias, tuff, sandstone and tuff; andesite ($\alpha hbK_2^{2,3}$ and $\alpha pyK_2^{2,3}$), with a prevailing presence of hornblende. Miocene sediments lie transgressively over the volcano-sedimentary complex, representing the outermost western parts of the Zaječar basin. They are represented by conglomerate, clays, and sands (M_2^2), namely sandstone, sandy clays and conglomerate (M_3^1). The spreading of Quaternary sediments is completely confined.

The terrain belongs to the Carpathian thrust of the Carpathian-Balkan and within its frame to the Dobrodol– –Grlica structural zone. Generally, in the Timok eruptive region, there have been singled out the following fault systems: longitudinal (NNW–SSE), transversal (NE–SW, rarely NNE–SSE) and diagonal fault of E–W strike.

Photogeologic analyze of the Timok region ruptures showed that the oldest fault trends (NN–SSE, NW–SE) were generated by the form and position of the old Hercynian Pluton-Tanda massif, in the eastern rim, and the Homolje–Kučaj massif, in the west. To this group also belongs the Nikoličevo fault (Fig. 1), along which there has been some vertical displacement; thus Miocene sediments are at the same level as older fractured and blocks-divided Cretaceous sediments. Such defined geological relations represented a predisposition for the deep circulation of groundwater, its heating and mineralization.

Hydrogeology

The following types of water-bearing formations can be singled out (Fig. 1):

1. Confined intergranular aquifer, within Miocene sediments.

2. Fissured aquifer in volcanic and volcano-clastic rocks, where can be distinguished:

a) The part above the erosive basis – low water bearing, gravitational water flow

b) The part below the local erosive basis – within fractured zones with more favourable water bearing (locally) and ascendant and descendent flow.

3. Upper Cretaceous marls and sandstones represent an aquitard or minor fissured aquifer, with local and limited water bearing.

4. Karst aquifer, within Lower Cretaceous limestones represents mainly a semi-open hydrogeological structure. Limestones in deeper parts are recrystallised, while groundwater (with higher temperature, t > 20° C) flows through faults and fissures.

Thermomineral water occurrences

Several authors has dealt with the thermomineral water in Nikoličevo. ŽIVKOVIĆ (1893) was the first who mentioned “fairly hot, sulphurous water” in Nikoličevo and later LEKO (1922) who stated that there were three hot water springs of which “the main one had a flow rate of app. 3 l/min, with a water temperature of 34° C”. MILOJEVIĆ (1973) noted that “in August 1964 three main springs had a total outflow of 0.45 l/s with temperatures 26–31° C”. The greatest research contribution was made by Milojević: two boreholes (wells) were drilled near the existing springs. Well B_1 was carried out in February 1972 and B_2, in May 1972. The occurrences (inflows) of thermomineral water along the boreholes profiles were (MILOJEVIĆ 1973):

B_1 well:
– at 16 m – Q = 0.1l/s, t = 28° C
– at 30 m – Q = 0.2l/s, t = 29° C
– at 106 m – Q = 33 l/s, t = 33.80° C

B_2 well:
– at 72 m – Q = 0.2 l/s, t = 29° C
– at 157.3 m – Q = 4.4l/s, t = 34.3° C

Water tapping was from fractured andesites and limestones, at the depths of 100–160 m (Figs. 2, 3), without an intake screen (open hole).

All thermomineral water occurrences (springs and well outflows) in Nikoličevo are situated within a radius of app. 100 m. Their total outflow (May 1972) was 17.5 l/s, whereby 16.9 l/s was from the wells, without pumping. The range of the temperatures was 19–34.9° C, whereby the well waters were characterized by higher temperatures (Tab. 1).

Table 1. Thermomineral water occurrences and flow rates – 17 May 1972 (after MILOJEVIĆ 1973).

Occurrences	Q (l/s)	t° C
Well B1	12.37	34.9
Tapped spring 1	0.02	24.8
Tapped spring 2	0.12	26.2
Untapped spring 1	0.22	28
Untapped spring 2	0.1	25
Untapped spring 3	0.1	27
Untapped spring 4	0.1	24
Untapped spring 5	0.02	19
Untapped spring 6	0.01	19.5
Untapped spring 7	0.0	20
Well B2	4.4	34.3

It is obvious that the initial B_1 flow rate of 33 l/s (February 1972) was reduced to 12,37 l/s (May 1972), as a consequence of: 1. the hydraulic influence (participation) of B_2 outflow of 4.4 l/s, and 2. an usual scalling with time, as a consequence of the accomodation of a piesometric level in the well radius.

Flow rate scaling

During the period August 2000 – February 2002, flow rates and water temperature measurements were carried out. It was established that the flow rate of the B_1 well oscillated within 2.22–2.53 l/s, while the flow rate of the B_2 well oscillated within 0.63–0.71 l/s, the total flow rate was 2.9–3.2 l/s (Fig. 4). This means that during 28 years (1972–2000), the total flow rate of the wells was very reduced, by more than 80 %.

Probably, the main reasons for the scaling are:

1. Well deterioration;

2. Depletion of the thermal water reservoir

Well deterioration processes could be:

– Physical (mechanical) causes-rock collapse in the intake unscreened hole parts of the wells or intensive deposition of particles carried from the aquifer in the

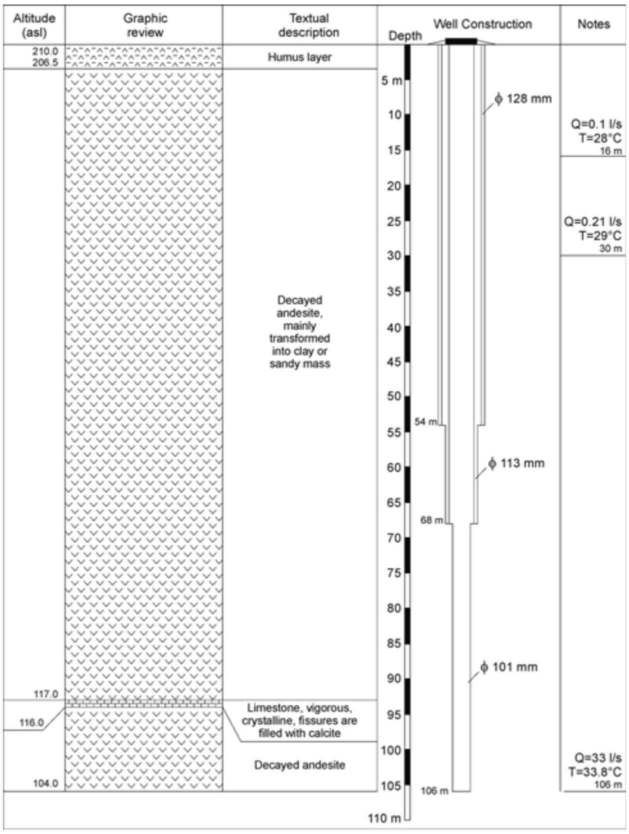

Fig. 2. Lithological profile and construction of well B-1 (after MILOJEVIĆ, 1973, simplified).

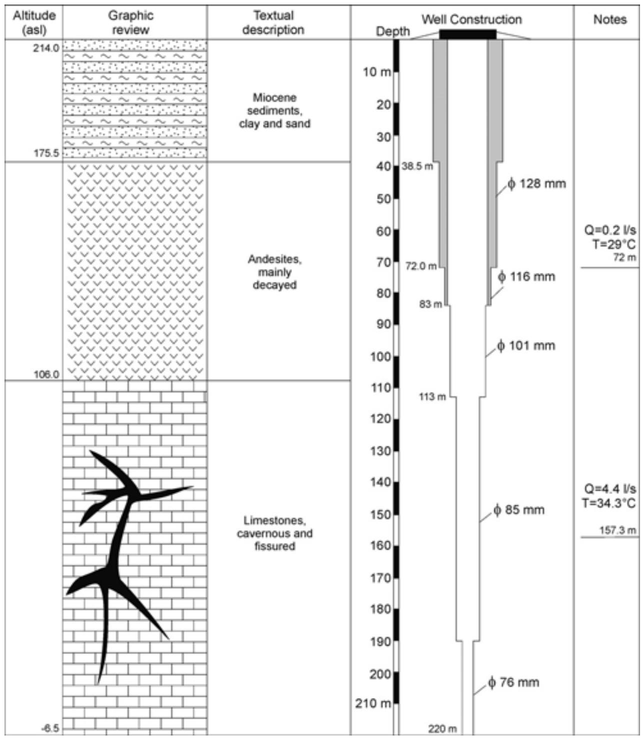

Fig. 3. Lithological profile and construction of well B-2 (after MILOJEVIĆ, 1973, simplified).

intake parts. Both of the mentioned causes are possible, because of the profiles properties (Figs 2, 3): decayed andesites (well B_1) or cavernous limestones (well B_2).

– Chemical incrustation of the intake parts and well casings and, also, of the transit aquifer zones, next to the holes. Generally, lowering of hydrostatic pressure (by groundwater tapping) and, also, changes of groundwaer velocity upsets the chemical, especially carbonate and iron equilibrium of groundwater, so incrustation occurs. The process is more rapid in the small intake spaces (drill diameters 76–101 mm, Figs 2, 3) and the manifestation of scaling is more noticable.

Reservoir depletion could be the consequences of a continual free (uncontrolled) long term outflow of wells.

Water quality

The water temperatures were also measured during the period August 2000 – February 2002: 35.5–36.6° C for the B_1 well, and 36.2–37.0° C for the B_2 well. (Fig. 4). The temperatures were higher by 0.6–2.7° C than the ones in May 1972 (Tab. 1).

According to the chemical composition (Tab. 2), thermomineral waters of the Nikoličevo spa are sodium carbonate ones, with the total mineralization fluctuating between 466 and 650 mg/l, low iron and manganese concentrations, pH value from 6.7 to 8.3, and the presence of undissolved H_2S gas. One of the essential features of the water is a higher fluoride (F) concentration (2.79–3.8 g/l). It should be stated that differences between the chemical components (Tab. 2) arise, partly, as a result of the analytical methods of different chemical laboratories. The most noticeable difference is the one between the concentration of H_2S gas (Tab. 2) in 1972 (4.5–5.1 mg/l) and in 1995 (0.28–0.38 g/l), but

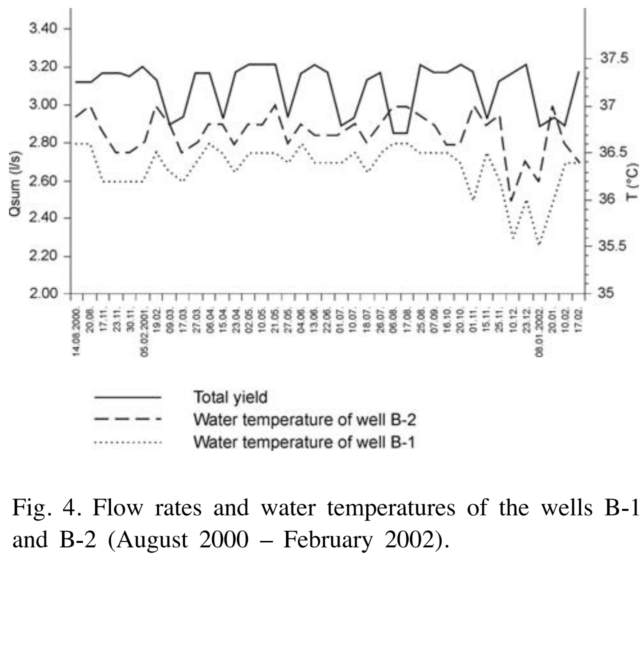

Fig. 4. Flow rates and water temperatures of the wells B-1 and B-2 (August 2000 – February 2002).

Table 2. Chronological survey of some chemical components of the thermomineral water.

Date Well	Total miner. (mg/l)	Dry residue (mg/l)	Na+K (mg/l)	HCO_3 (mg/l)	Fe (mg/l)	Mn (mg/l)	H_2S (mg/l)	F (mg/l)	pH
1972 (1)									
B-1	541.2	487,7	147	-	0.3	0.0	-	-	7.0
1972 (2)									
B-1	-	500	147.5	366			4.25		7.6
B-2	-	490	147.5	366	-	-	5.1	-	7.6
1995									
B-1	650	-	134.2	328.8	0.17	<0.01	0.28	3.8	7.5
B-2	650	-	131.7	325.5	0.13	<0.01	0.38	3.6	7.6
1997.									
B-1	-	519	-	-	-	-	-	-	8.12
B-2	-	510	-	-	-	-	-	-	8.04
11.09.'00									
B-1	503.66		143.5	372.0	0.01	0.0	-	-	7.95
B-2	502.82		138.1	378.6	0.03	0.0	-		7.98
08.06.'01									
B-1	490.35		155.2	426.9	0.01	0.0	-	-	6.94
B-2	455.67		138.2	369.4	0.02	0.0	-	-	7.49
07.09.'01									
B-1	498.07		147.6	391.6	0.01	0.0	-	-	7.30
B-2	489.96		138.6	378.6	0.01	0.0	-	-	6.88
16.10.'01									
B-1	466.80		140.6	391.6	0.01	0.0	-	-	7.35
B-2	461.77		126.2	391.6	0.01	0.0	-	-	6.70
09.11.'01									
B-1	-		-	-	<0.05	<0.025	-	-	8.30
B-2	-		-	-	<0.05	<0.025	-	-	8.30
10.01.'02									
B-1	-		-	-	<0.05	<0.025	-	-	7.90
B-2	-		-	-	<0.05	<0.025	-	-	8.00
26.02.'02									
B-1	-		-	-	-	<0.025	-	-	7.70
B-2	-		-	-	-	<0.025	-	-	7.90
06.09.'02									
B-1	-	400	-	-	0.03	<0.01	-	2.82	7.50
B-2	-	400	-	-	0.06	0.01	-	2.79	7.70

the availlable results of only two gas analyses are insuficient for a proper interpretation.

On the basis of the hydrochemical results, the water belongs to the category of sodium carbonate, fluoride, isothermal, oligomineral ones, suitable for balneotherapy, drinking (limited, because of fluorine concentration) and recreation purposes.

An analysis of gas composition show the nitrogen type and vadose origin of the water (DIMITRIJEVIĆ 1975).

Conclusions

Thermomineral water of Nikoličevo Spa was tapped by two wells, at a depth of 100 to 160 m. A karst-fissured aquifer was formed within Cretaceous andesites and limestones. Thermal character, as well as certain chemical properties, result from circulation of the groundwater deep in the Nikoličevo fault zone.

During the period 1972–2000, scaling occured and the flow rate decreased by more than 80 %, from the initial 17 l/s to 3 l/s, as a consequence of the deterioration of the wells and reservoir depletion. The reduced flow rate and, consequently, slower groundwater movement, resulted in the water temperature rising by 0.6–2.7° C .

The annual regime (August 2000 – February 2002) of the wells, flow rates and the water temperature were assessed as quite stable, without significant influence of the annual meteorological cycle.

The chemical composition and water temperature enable manifold utilization, especially in the domain of balneology and recreation, but the current low flow rate is limiting.

The depth of the intake zones and the existence of overlaying confining beds, as an insulator from (potential) surface pollution, are the favourable aquifer vulnerability factors.

In order to use and sustain this natural resource, the following should be done:

• TV, calliper, temperature and/or flow-velocity logging of the holes, if possible (because of the small diameter), in order to identify the inflow and incrustation zones in the holes and causes of the deterioration.

• Drill a new well or wells, next to the location of the existing one(s), of suitable constructions, primarily of larger drill diameters. Construction and position of the intake parts will depend on the results of wells logging. As to the location B_1, it should include greater depth from 160–170 m as well. This will provide considerably larger flow rate(s) than the current one(s).

• Proper sanitation (dysfunction) of the existing holes, because of low production, as well as sanitary protection of the resource.

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Резиме

Термоминерална вода Николичевске бање (источна Србија)

Природни извори термоминералних вода, слабе издашности, налазе се у селу Николичеву, у источној Србији, у оквиру тзв. "Тимочке еруптивне области", на cca. 7–8 km североисточно од Зајечара. Термоминералне воде егзистују у оквиру комплексне карстно-пукотинске издани, формиране у оквиру доњокредних кречњака и горњокредних вулкано-кластичних стена, а предиспозицију за њихово формирање (дубоку циркулацију) чине раседи правца пружања ССЗ–ЈЈИ.

Двема истражним бушотинама из 1972. године, дубина 106 и 220 m, констатоване су изванредне квантитативне и квалитативне карактетистике: сумарна издашност од cca. 17 l/s (самоизливом) и температура вода од 34–35° C. Режимским осматрањима спроведеним у периоду август 2000. – фебруар 2002. године, установљено је да је, услед процеса старења бунара и, вероватно, делимичне исцрпљености "резервоара" термалних вода, издашност опала за cca. 80 % и износи 2,9–3,2 l/s, док је температура вода, због успореније водозамене (мањег истицања) повишена на 35,5–37° C. Стабилне величине издашности и температуре, мерене у периоду 2000. – 2002. год., указују да не постоји осетан утицај метеоролошког циклуса на режим вода.

Према хемијском саставу, који се за наведени 30-годишњи период може оценити као стабилан, воде се сврставају у натријум-хидрокарбонатне флуоридне олигоминералне изотерме, са широким спектром могућности коришћења. У циљу ефикаснијег коришћења овог изванредног ресурса, потребно је санирати постојеће и израдити нове водозахвате одговарајућих конструктивних карактеристика.

Instructions for authors

Geološki anali Balkanskoga poluostrva is issued annally and publishes original scientific contributions over a wide range of topics in any field of the geological sciences. The journal accepts papers in English of moderate length, not exceeding 50 double spaced manuscript pages, including illustrations.

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The title of the paper should be short, but expressing the principal aim of the paper.

The abstract must be concise, not more than 200–250 words, and should be informative, stating the results presented in the article rather than describing its contents. Inclusion of references in the abstract is not recommended.

After the abstract, list 5–8 **keywords** which describe the subject matter of the work. They should be arranged from general to more specific ones.

The **text** should be written as clear and understandable as possible. Use up to threee levels of headings. Their hierarchy should be indicated in the left-hand margin of the text. Italics are used only for the name of genera and species, or if a word is italicized in the original title. References should be cited in the text as follows: DAMBORANEA (2002) or (DANBORANEA 2002) for a single author; FÜRSICH & HEINZE (1998) or (FÜRSICH & HEINZE 1998), for two authors; RICCARDI *et al*. (1991) or (RICCARDI *et al*. 1991) for multiple-author works.

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AGER, D.V. 1963. *Principles of Paleoecology*. 318 pp. McGraw-Hill, New York.

OWEN, E.F. 1962. The brachiopod genus *Cyclothyris*. *Bulletin of the British Museum (Natural History)*, *Geology*, 7 (2): 2–63.

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SULSER, H. 1996. Notes on the taxonomy of Mesozoic Rhynchonellida. *In*: COOPER, P. & JIN, J. (eds.), *Brachiopods*, 265–268. Balkema Press, Rotterdam.

Acknowledgments should be as short and concise as possible.

A **summary** (up to 15% of the paper) is published in Serbian and should contain the essence of all new data and the conclusions.

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