THE HYDROGEOLOGICAL RELATIONS OF THE THERMAL KARST OF THE BÜKK MOUNTAINS BASED ON MONITORING DATA

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ABSTRACT

The Bükk Mountain area is located in Northern Hungary. The size of the naked (cold water) karst of the Bükk is 207 km² and the size of the water catchment area is 230 km². The thermal karst water system of the Bükk is an estimated 1000 km² and its boundaries cannot be delineated exactly.

Firstly, in our research the geological, geophysical and thermal maps of the Bükk have been investigated. Thereafter we prove the relationship between cold and warm karst water in correlation investigations which were based on water level and temperature data of the Bükk monitoring system. According to the correlation investigations the cold and warm karst water bodies are related which cannot be separated into two independent aquifers.

These investigations can help to plan the optimum water utilization and they can provide information for the next water explorations.

INTRODUCTION

The cold karst water area of the Bükk Mountains (Northern Hungary) is surrounded by a significantly extended thermal karst water area (yielding karst water with temperatures exceeding 30 °C) in the east, west and south (Figure 1; [1]).

About two dozen karst springs and thermal wells can be found at the rim of the mountains and the surrounding area, yielding tepid or warm (springs), or even warm or hot thermal water (wells) (Figure 2). The area around the mountains is covered with a sediment layer. Their water catchment areas are situated in the limestone areas of the Bükk Mountains. The cold karst water system of the Bükk is regarded as a unified system. The data presented by Nv-17 karst water monitoring well are accepted to represent typical karst water levels. In the present paper we are concerned with the relations of the open and covered karst in the area with regards to karst waters.

Miskolc is the third largest city (with a population of around 170,000) in Hungary with a famous Miskolctapolca cave-bath based on the thermal groundwater coming from the deep section of the karstic Bükk Mountains. This huge karst reservoir is also the main water resource for the city water supply in Miskolc. The city waterworks carries out intensive water production from the two main wells (namely the New-well and the Thermal-well) at the rim of the Bükk Mountains. The New-well discharges the upper cold part of the karst aquifer system with an average rate of 30,000 m³/day. The Thermal-well provides warm water for the world-famous cave-bath from the deeper section of the karst system with an average production rate of 2,700 m³/day [2, 3].
The size of the unconfined (open) karst system is about 207 km$^2$ (marked by numbers 116; 118; 130; 134 in Figure 2) and stretches from the east to the west in patches. It means that the line of bearing of Carboniferous-Permian (134; 141) and Triassic-Eocene (116; 118; 130) carbonate rocks is east to west. (The most significant faults are also oriented from the east to the west but at the rim of the mountains faults perpendicular or at an angle to it are also to be found.)

The precipitation on the open (unconfined) karst of the Bükk infiltrates the karst, and either leaves it through springs, or moves towards the Alföld (Great Plain) region through the limestone layers stretching beneath the Cenozoic sediment layer, due to the pressure differences of the karst water relief of the Bükk.

Due to ground heat (convection) the cold karst water warms up along its flowpaths. (Note: the convection value of 100 mW/m$^2$ measured at the Great Plain (Alföld) is gradually decreasing as it reaches the rim of the mountains. In the middlemost area of the Bükk it is as low as 40 mW/m$^2$ [4].

For technological reasons, the dividing line between cold and warm (karst) water is drawn at a temperature of 30 °C in Hungary. (Nature doesn’t allow for such sharp line to be set but for technological and legal reasons let us accept this value as the dividing line.)

The 30-degree-Celsius isotherm is located under the Bükk Mountains at a depth of 900–1400 m. Its depth is rapidly decreasing towards the rims. There is no possibility of exploiting the thermal karst water in the Bükk, it could only take place in the covered karst, further away from the Bükk’s rim. The reason for this is that the thermal karst water can be found at great depths, and it has direct hydrological connection to the cold karst water. Caves containing thermal karstic formations are found at the brim of the Bükk. These formations were created by upwelling karst water. Despite this, the thermal karst genetics remains questionable for many scientists.

The largest karst spring of the Bükk (cold and warm water spring group) is at Miskolctapolca. The location of thermal karst water springs and wells are specified on Figure 2. The Miskolctapolca spring group is located at 127 m aBS (above Baltic Sea) level.
The maximum karst water level at the Bükk Plateau (Nv-17) has been measured 550 m aBS level. The average of karst water level between 1992 and 2012 was 530 m aBS level. This means that since the karst water level at Miskolctapolca is at 127 m aBS, and the average and maximum water level of the open karst water system in the Bükk area is at a much higher level, it generates a 40–42 bar pressure difference, thus causing the water to flow [5].

The large open karst is “well karstified” from the surface to 300 m underground. The cold water infiltrating the large open karst is moving in the upper zone of the karst limestone
layer which stretches under the sediment layer in the Miskolc pilot area of the Bükk (Figure 3) [6].

The thickness of the “well karstified” zone is probably about the same in the case of covered (confined) karst but drillings did not penetrate to deeper than 100 meters. The carbonate layers are located deeper and deeper. Around Kőröm (Sajóhídveg), the base temperature exceeds 100 °C at a depth of 2000 m below Baltic Sea level. The 30 °C isotherm is not marked on the Figure. The presentation of values 20 and 40 °C was based upon, among others, the published data of the Pávai Vajna well which is highly debated even today [13].

In order to determine the exploitability of karst water it is very important to have more accurate data, but based on the data of the karst water monitoring wells, caves and springs, we can conclude that the 30 °C isotherm is located in more depth even in the area marked than it is shown on the Figure 3. The drilling at Mályi in 2010 reached a 2300-meter depth. It is not shown on the relevant figure as the investor treats the official data of the drilling confidential. The temperatures measured in the drill are very similar to the values measured in the monitoring well at Kőröm.

The open karst water catchment area of Eger (including Egerszalók and Demjén) is neither as large nor as unified as the Miskolc aquifer. Due to heavily tectonized structure and significant karsting, the karst water warms up in the depth and moves along the faults (Figure 4) [7]. The temperature of the karst water reaching the surface is almost the same even if it comes from depths of 300 or 900 m below Baltic Sea level (65–68 °C). At the brim of the mountains, some wells yield water colder than this. The well K-12, drilled in 2011 in Demjén, is 1514 meters deep. The highest temperature measured in the K-12 well is 79 °C, and karst water that reaches the surface is 73 °C. The water cools 6 degrees on its way. In the Miskolc area, from the depth of 400–500 m below Baltic Sea level, the temperature of the karst water is 40–45 °C.

Figure 4.
Overview of the thermal karst system in Eger surroundings, without Demjén K-12
[Based on Aujeszky 1974; Izápy and Sárváry 1992; Lénárt 2012]
RESULTS

Figure 5 shows the fluctuation of the annual volume of water, exploited in the surroundings of the Bükk and discharging from springs at the brim of the mountain.

The water is mostly used for medical, therapeutic and bathing purposes in the region, but the communal use is also significant. At certain places it is also sold as drinking water. The greatest possibility for development is for energy production. Most of the bathing establishments cool the water by using heat exchangers, but the utilization of the wasted heat for energy production is still very limited. Drillings have been done in Mányi and Kistokaj in order to support the central heating system of Miskolc city but the system is not yet completed.

The closest relationship is considered to be the one between the water levels of Nv-17 and the Termál spring (Figure 6).

(In Figure 2 the Thermal spring is marked as “Miskolc warm karst water”.) One of the reasons for this is that the distance of the cold and warm springs at Miskolctapolca is about 80 m, and between them limestone and mountains rim gravel layer can be found. Also, the flood overflow of the warm spring (Termál spring) is located only less than a meter above the flood overflow of the cold spring. It means a tight spatial relationship. (About 100 years ago there were many dozens of cold, tepid and warm springs but in order to concentrate the water yields, for water exploitation reasons, the number of springs basically decreased to two.) Also, above all the water yielding objects under examination, the Termál spring is situated closest to the karstic feeding area [8–11]. The sole most important use of the water of the Termál Spring is to supply water to the Cave Spa (Barlangfürdő). We consider the relationship very tight (Figure 7) between the pressure levels of Nv-17 and the Vízmű and Selyemréti I. thermal well of the water company. (These two thermal wells are under “Miskolc thermal water” on Figure 2, and their distance is about 1 km.) Both thermal wells basically react immediately in the same way and for longer durations when the cold karst
water pressure level is on its peak. (Naturally due to the fluctuation of water exploitation it is not possible to follow the changes of smaller magnitudes.) They are situated at a greater distance from the feeding area, and they yield the water moving in the limestone layers that are the subsurface extensions of the east-to-west patches of the open karst aquifer. The relationship is much looser in case of the Nv-17 and the wells of Egerszalók and Demjén (Figure 8). For one thing, these are located much further away from the feeding area, and also situated perpendicular to the carbonate patches stretching east to west [12]. These are shown in Figure 2 as “Egerszalók, Demjén thermal karst water”. The distance between the two wells of Demjén is 1 km. The distance between the wells of Egerszalók – De-42 and De-42a – is about 15 meters. Well De-K-11 is closest to the Mátra Mountains. The Mátra is a mountains range whose surface is non-karstic rock. The above-mentioned Demjén K-12 well is the deepest in the area, with its depth of 1514 meters. During its test run it affected the Demjén K-10 and Demjén K-11 wells the most.

![Figure 6.](image)  
*Comparison of the water levels recorded at the Nv-17 karst water monitoring well and the Termál spring of Miskolctapolca*
Figure 7.
The relationship of the Nv-17 karst water monitoring well and 2 thermal karst water wells of Miskolc

Figure 8.
The relationship of the Nv-17 karst water monitoring well and 4 thermal karst water wells of Egerszalók-Demjén
CONCLUSIONS

According to the correlation investigations which have been based on the water level data of 20 years long measurements, the relationship between the cold karst water level and warm karst water level (pressure level) is clear but its tightness differs. The tightness of the relationship increases in case of wells situated in the east-west carbonate patches, but it weakens in case of wells situated perpendicular to such patches.

Comparing the temperature data with geological and thermal maps, it can be stated that the temperature of the thermal karst water increases when moving further away from the mountain boundaries, evenly with the depths in the Miskolc area. But due to the horst structure in the area of Egerszalók and Demjén the increase of temperature is independent of depth.

The thermal karst water moves along tectonic zones (Egerszalók, Demjén area) or in the karstic zones which were naked (unconfined) karst surfaces (Miskolc area) in the earlier geological ages.

According to available data, the cold karst water of the Bükk with its 42 bar pressure pushes the thermal water (30 °C) into 900–1400 m deep layers. So the thermal water explorations in the centre of the Bükk Mountains and its rims are needless. Because the zone with the necessary temperature is at great depths or the porosity of the aquifers in these depths is very low (it cannot serve enough water). If there was adequate porosity (for example a cave) in the required depths, the cold karst water would flow into the well and it would cool off the thermal karst water. Also a confirmation of this statement is the thermal karst water exploration work of F. Pávai-Vajna in the centre of the mountains near Lillafüred, which actually failed.

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