# CAVE-HUMAN INTERACTIONS IN TWO HUNGARIAN CAVES

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**Summary**
Between 1996 and 1998, the Physiology, Climatology and Microbiology Working Group of the Hungarian Speleological Society organised three expeditions to two Hungarian caves with major differences in their climate. Our goal was to investigate cave-human interaction, on the one hand tracing the physiological changes taking place in the human body, on the other hand examining to what extent the human presence changes the environment in the cave. The human physiological experiments included measurement of body-temperature, heart-rate, blood-pressure and changes in the liquid and ion balance, extended by blood-gas-analysis from the second expedition and by impedance-cardiography in the third expedition. The record of changes in the caves' climate has helped us to evaluate the biological data, but the data can be evaluated separately as well. They show the natural state of the caves and the changes the expedition caused. During the climate measurements, besides recording temperature, humidity and air-pressure, we made a trace-gas-analysis of the air-space and also measured changes in radon-transport. The measurements were completed by bacteriological sampling and examination of participants' endoflora.

## Introduction

Between 1996 and 1998 three well equipped expeditions investigated two Hungarian caves. Researchers of various fields of expertise conducted complex series of tests to study interactions between caves and humans. They examined the effects of human presence on the cave environment, and the changes in the human body caused by staying in the cave for a long time, with roughly the same methods in two genetically different caves. During the tests for the basic research we provided extreme conditions for the participants. We collected data to improve accident prevention in caves and the effectiveness of medical activities (therapy) in caves, while also paying attention to nature conservation, and how the cave reacts to the presence of humans, which way and to what extent do environmental variables change, as well as to their reversibility. Ten participants visited the Cserszegtomaji-kútbarlang twice and the Baradla-cave one time, where they spent a week. Before moving in, we recorded the caves original climatological and bacterial characteristics. During our stay we monitored the changes in those parameters. After leaving the area we recorded the schedule of the cave's self-restoration process. We collected samples from the subjects living in the cave and compared the physiological changes with the surface control group, whose members have supplied the other half of the group. The cave group had physical exercise, in the form of speleological research.

## Studied caves

The Baradla-cave can be found in North-Eastern Hungary in the Gömör-Torna Karst. The enclosing rock is upper-triassic Wetterstein Limestone, with some parts reaching into lower-triassic Gutenstein Limestone. It was formed during the Pleistocene age, its huge corridors have been created by water oozing through the rocks. The cave consists of a 7 km long main corridor and several sub corridors, that make up a total length of 23 km. Average width of the corridors are 10.5 m; average height is 7 or 8 m. Chambers are up to 60 m long and 50 m high. Sub corridors tend to be smaller in size. The main corridor begins at the main entrance, and ends at the entrance at Jósvafő. After considering the direction of the draught (from Aggtelek towards Jósvafő), we placed the camp at the boating-lake's farther end, to minimise the effect of the incoming air.

The Cserszegtomaji-kútbarlang is in South-Western Hungary at the south-western edge of the Keszthely Hills. It lies 53 meters deep between layers of Pannon limestone and Triassic main-dolomite. The original dolomite surface has been subjected to karstic erosion. The thick deposits - mainly sandstone - has filled the depressions in the dolomite, entering even the smallest cracks. In the covered, pressurised deep-karst the conditions were right for the formation of recesses. It was preceded by the silification of the sandstone; coagulation to rock was a condition of the conservation of the forming holes. That's why the arches of the holes formed by the thermal water that had dissolved the dolomite are made of sandstone, preserving the negative imprint of the dissolved dolomites fossil surface. The cave was discovered in 1930 while digging a well, that well is still the only entrance, the total length of the cave is 2400 m in a total area of 150 x 150 m forming a labyrinth. The average length of the corridors is 1-1.5 m, on the northern part of the cave the majority of the corridors are short with multiple bifurcation's. Larger chambers can only be found in the southern parts, their height can be up to 2-3.5 m, and their width about 5-18 m.

## Cave climate

Climate measurements were designed, to show the changes between the cave's normal conditions and the conditions modified by the human presence. The surface's meteorological parameters were recorded by an environmental protection survey van. In Cserszegtomaj, our main measuring point, due to the labyrinthical layout of the cave was at the entrance at the only known ventilating point, 53 meters deep in the well. To strengthen the airflow we narrowed the 1.5 by 1 m entrance to 15 by 15 cm; this way we had a forced airflow, with a measurable speed. In 1996 we used handheld devices once every half-hours, for our measurements of temperature, humidity, airspeed, air pressure. In 1997 we added heat-flow and soil-moisture measurements to our repertoire along with $CO_2$ measurements at the campsite. This was the year, when we measured ozone, nitrogen-oxides, sulphuroxides, methane and hydrocarbons in the samples pumped into the survey van through a plastic pipe. We also recorded the changes of radon and it's daughter elements' level.

In the Baradla cave we extended our goals with the study of possible medical applications. To avoid any interference with tourism, we placed our measuring points far away from the routes of regular tours, approximately 900 meters from the entrance. Due to a concert held in the cave we had the opportunity to study the effects of the presence of hundreds of people, and the regeneration of the normal conditions, with our instruments placed, temporarily in the orchestral chamber. The instruments used in this experiment were similar to the ones used in Cserszegtomaj, but we made our measurements, (mainly temperature) at multiple heights, in the huge chamber. Similarly the surface's conditions were recorded by the same survey van.

During the first expedition to Cserszegtomaj we recorded the effects of the carbon dioxide and radon rich air coming from the depths of the cave, due to the extremely low air pressure. Except for the first two days we were unable to access the inner parts of the cave because of the high (more than 3 %) $CO_2$ levels. We recorded a really unique state of the cave, according to the automated radon transport measurements the probability of such a long depression is lower than 1%. The tests, repeated in 1997 under rising and high air pressure, proved the Cserszegtomaj cave's climate's dependency on air pressure, and by the detection of a steady rise of the temperature at the campsite it gave a warning of the small cave's low tolerance of human presence.

The climate studies in the Baradla cave, even with the detection of a minor rise of temperature, have shown the regenerating capacity of the enormous volume of air in the cave. The 150 persons attending the concert, even with the aid of the heat given off by reflectors couldn't change the climate significantly, or the normal values were restored quickly. This effect is very promising if we want to use the cave for therapy, also it's significance in natural preservation is important since the cave is the most visited touristic cave of Hungary.

**Cave radon**

The radon concentrations in the cave have been monitored from the 1970's. It was soon discovered, that from time to time extremely high concentrations build up, sometimes showing tens of kBq of activity per cubic meter. The Cserszegtomaj cave stands in the focus of attention of researchers from 1993. Prior to, and during the expedition multi channel monitoring instruments have been installed that recorded the concentration of 222Rn, the air pressure and temperature every hour. The air enclosed in the cave has a really high radon content, usually when the outside air-pressure is low. So during the 1996 camp the activity-concentration of the air in the inner parts of the cave has exceeded 45 kBq/m3. To provide background data for the physiological studies we have supplied the participants with personal dosimeters and measured the dose-equivalent received by the subjects (16 mSv). The dosimeters worn by people moving around the cave and installed in the camp have shown a difference less then 10%, that indicates, that under constantly low air pressure the radon is distributed evenly through the entire cave. This observation contradicts with our prior experiences, that suggested half the activity near the entrance, than in the inner parts of the cave.

In 1997 prior to the descent of speleologists (until 05. 21.) the level of radon was increasing slowly and steadily, showing great differences between different parts of the cave, due to local variations in the number of fractures of stone, or in the flux. Then a strong and rapid rise in the air pressure caused the radon levels to drop to near 0 at the entrance, and to 1/4, 1/3 of the original level in the inner parts of the cave.

The Baradla cave has many contacts with the outside air, and it has a huge amount of air inside, so it doesn't have as high concentrations of radon as the Cserszegtomaj-cave. Instead of the 45-50 kBq/m3 in 1996 or the "low" 15-16 kBq/m3 in 1997, here we have registered values between 600 and 1300 Bq/m3 with the average of 840 Bq/m3. A correlation between the concentrations of $CO_2$ and Rn can be observed in this case too.

**Cave microbiology**

Microbiological tests are special parts of the researches of caves. Their significance is in uncovering the cave's own flora and in tracing its changes, it's also interesting to follow the fate of the microorganisms imported by the airflow or by the crew. During the expeditions we have studied the mesophyl bacterial content, of the air in both caves, distinguishing between different species of bacteria. We have analysed the nose and throat mucus of the participants and in 1996 we even collected faeces, but since they hadn't shown significant changes, we had not done so after 1996. The air's bacterial tests have been conducted using sedimentation, gelatine-membrane and culture-medium methods, and they proved the air's high self-cleaning ability in both caves. The samples suggest, that although bacteria that get into the cave cannot settle down. During the first camp we have found a steadily decreasing number of bacteria, and the second time the number of bacteria remained constant despite the germ rich air flowing into the cave. Even in the extreme conditions of the Cserszegtomaj cave, the species-makeup found was not much different from the usual cave dwelling species. Pathological bacteria have never been found. By studying the endoflora of the participants we have concluded, that the risk of droplet infection is low. We have isolated pathogens or quasi pathogens ((Moraxella catarrhalis, Staphylococcus aureus, Haemophilus influenzae) in many members of the crew, but they have not changed hosts (moved to other persons). In the case of Staphylococcus aureus we discovered that all the infected persons had their own unique strain. In the Baradla cave the person who has been infected by S. aureus, H. influenzae, or M. catarrhalis prior to the expedition became bacterially negative by the end of the expedition.

In the case of the Baradla cave the water oozing through the covering layer of rocks, and the water of the spring in the cave has a great importance, so we have subjected them to bacterial tests too. In the dripping water we have always found a small number of bacteria as well as a small number of species, usually Baccillus and Alcaligenes. We have not found fungi or faecal-indicator bacteria. We have tested the water of the creek at the lake, unfortunately we have found high levels of Enterobacter, Escherichia coli, Flavobacterium, Baccillus and Staphylococcus species.

**Health of cave explorers**

We have studied the effects of the extreme climate of the cave on the 10 members of the camp. The inhabitants of the surface camp have also subjected themselves to medical tests, playing the role of a control group. The tests we conducted were: Before and after the camp: complete laboratory examination (full blood count, GOT, GPT, LDH, yGT, KN, creatinine, SeFe, ScBi, full urine analysis and TVK). Daily during the camp: blood pressure, body temperature, heart rate, fluid balance, from venous blood: glucose, Na+-, Ca+-, Mg++-, ions, LDH, CPK enzymes, from dipstick urine tests: haemoglobin, red blood corpuscles, white blood cells, sugar, acetone, UBG, bilirubin, and specific gravity, with on site blood gas analyser, using arterial capillary blood: pCO2, pO2, O2sat, pH, BE, EBE, BB, SB and BIC. In 1998 the tests also included: Na+-, K+-, Ca++-Cl--ions, lactate and glucose. In 1996-97 we've done all the tests above, and additionally a PEF test, and in 1998 before and after the camp we've done tolerance tests and impedance-cardiometry tests.

The compilation of this huge database could take years, but even at this moment we can report a few interesting findings. In the $CO_2$ rich environment of the Cserszegtomaj cave, we've measured the $CO_2$ load (that is the average volume of inhaled $CO_2$, using an average air intake of 20 litres/minute), that shows the dynamics of the changes, a compares well to the control group, showing differences of orders of magnitude. In the Baradla cave these numbers are less important because the $CO_2$ levels are much lovers, here the low temperature provided challenge for the participants. We have to admit, that in 1998 members of the surface control group had to spend 4-6 hours daily in the cave, due to technical difficulties, so this way they showed all the physiological changes of the cave group, just later.

In all of the three expeditions we found a change in the fluid balance. The cold - and in Cserszegtomaj the high $CO_2$ concentration - caused contractions of peripheral blood vessels, this way the central volume became higher, so the amount of urine was more than the fluid intake. Also because of the cold bilirubin and uribilinogen has appeared in the urine. This can partly be due to the hastened ageing of red blood corpuscle, but we suspect that changes have occurred in the processes in the liver, because of the temperatures just over 10 degrees Celsius, the $CO_2$, or maybe the high Rn concentration. The protein appearing in the urine samples suggest lover kidney threshold. We were surprised to find that high $CO_2$ concentration didn't cause acidic changes in the blood, instead the pH of the samples moved towards alkalic. The decrease in the serum K+ ion, despite the decrease of serum Na+ due to the increased diuresis, and the already mentioned red blood cell damage, was similarly surprising. The impedance cardiograph results also support our theory of the centralised circulation. The Z0 (chest base impedance) values show a steady decrease in the members of the cave group, and after a brief delay the effect has appeared in the control group as well, but to a smaller degree.

Summing up our experiences we can declare that the cave environment weakens the peripheral circulation, causes a central volume surplus, and the change can approach the lower limits of physiological variables without producing subjective symptoms. This phenomenon, along with the change in the acid-base balance and the K+ ion level, can be a cause of sickness and accidents in the cave. The fact, that the members of the surface control group, who have spent a few hours every a day in the cave, showed the same physiological changes, is expected to rise a few eyebrows among the doctors involved in cave therapy too.

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