KARST WATER PROTECTION PROBLEMS INDICATED BY DRIPPING WATER ANALYSES IN BUDA THERMAL KARST AREA

TEŽAVE Z VAROVANJEM KRAŠKE VODE, KOT KAŽEJO ANALIZE PRENIKAJOČE VODE V TERMALNEM KRASU V BUDI

KATALIN TAKÁCSNÉ BOLNER

Izvleček UDK 556.38:551.23(439)

Katalin Takácsné Bolner: Težave z varovanjem kraške vode, kot kažejo analize prenikajoče vode v termalnem krasu v Budi

Da bi ugotovili izvor onesnaževanja termalnih izvirov v Budi, so pričeli 1987 redno opazovati kvaliteto prenikajoče vode v 5 večjih fosilnih jamah, ki so med sedanjimi izviri in urbanimi površinami madžarske prestolnice. Sezonske analize prenikajoče vode s skupno 25 mest so pokazale relativno stabilno kemično (kloridi, nitrati, sulfati) in/ali občasno bakteriološko (streptokoki fekalnega izvora, koliformne bakterije, *clostridium, pseudomonas*) onesnaženje na vseh mestih, ne glede na globino, skalno površino ali značaj okolja. Človekov vpliv, ki ga kaže to onesnaževanje, izvira iz zimskega soljenja cest, uporabe umetnih gnojil in pesticidov v vrtovih, poškodb plinovoda in kanalizacije, črnih odlagališč in gradbenih del, ki zajamejo velike površine. Vse to zahteva revizijo varovalnih ukrepov.

Ključne besede: Buda gričevje, fosilne termalne jame, prenikajoča voda, kemizem, bakteriologija, vpliv na okolje

Abstract UDC 556.38:551.23(439)

Katalin Takácsné Bolner: Karst water protection problems indicated by dripping water analyses in Buda thermal karst area

To determine the origin of contamination in Buda thermal springs, regular analyses of infiltrating water quality were started in 1987, in the five largest relict caves occupying a position midway between the modern springs and the urban surface environment of the Hungarian capital. Seasonal analyses of dripping waters representing altogether 25 sites have revealed rather stable chemical (chloride, nitrate, sulphate) and/or occasional bacteriological (faecal streptococcus, coliform, *clostridium, pseudomonas*) contaminations for all sites regardless of their depth, surface rock and environment character. The human impacts indicated by these contaminations are defrosting of roads by salting, fertilization and chemical treatment of gardens, damage to pipelines and sewage systems, illegal desiccation pits, and construction work disturbing large surfaces; which reflect to the necessary revision of current protective measures.

Key words: Buda Hills, relict thermal caves, dripping waters, chemistry, bacteriology, environmental impacts

Address - Naslov
Katalin Takácsné Bolner
Institute for Speleology,
Ministry for Environment and Regional Policy
Költö u. 21,
H-1121 Budapest
Hungary

INTRODUCTION, GEOLOGICAL-HYDROGEOLOGICAL SETTING

The situation of the Buda thermal karst within the residental area of a capital city is unique in the world. Modern thermal spring activity is represented by several warm springs discharging waters of 20-60°C in two major groups along a significant tectonic line parallel with the Danube. The extended cave systems and freshwater limestone deposits elevated to 300 m above the current spring level mark the subsequent stages of a two million years karstic development.

Evolution of this thermal flow system started in the Neogene, when uplift of the Buda Hills area exposed the karstifiable Triassic and Eocene carbonates to karstic infiltration again; while the same carbonate formations were at considerable depths in the adjacent sedimentary basins. This geological and structural situation resulted in the evolution of a deep circulation system.

The thermal flow is fed by karstic infiltration of open karst areas in the northern part of the Buda Hills and farther units of the Transdanubian Mountain Range. The flow is maintained by pressure differences caused by different geodetic heights and by warming of waters at depth due to the above-average geothermal flux of 5°C/100 m. The ascending flow is directed by confining impermeable sediments towards the marginal carbonate outcrops of Buda Hills, which are at the same time the tapping points for normal descending karstic waters *(Fig. 1.)*. Most of the caves of the Buda Hills area are interpreted as relict spring conduits enlarged due to the corrosion effect of mixing ascending and descending waters with different temperature and chemistry.

The first signs of thermal spring activity are represented by Pliocene freshwater limestone deposits. Further uplift of the Buda Hills during the past two million years resulted in repeated repositioning of spring outlets, and thus the evolution of several freshwater limestone and cave levels. The most extended cave levels correlate with the elevations of Lower and Middle Pleistocene limestone deposits.

The most spectacular group of thermal karst features can be found in the 2nd district of Budapest, in the so called Rozsadomb region. Within this area of 10 kmý, there are about 70 caves with a total length of explored passages more than 29 km *(Fig. 2.)*. The largest systems are situated 1-2 kms to the NW of the largest group of modern thermal springs. Although the thermal springs and freshwater limestone deposits of the area were utilised already by the Romans, the presence of large caves has been discovered only since the beginning of the 20th century, as a result of human interferences - like quarrying or construction work - associated with the urban development of the region. More than the half of the currently known passage system was discovered only during the past fifteen years; while intensive building on the area started in the early seventies.

INVESTIGATIONS ON ENVIRONMENTAL IMPACTS

The position of the thermal springs and caves within a capital city offer unique possibilities for their touristic and therapeutic utilisation, but, on the other hand, the urban environment has several unfavourable effects on them. Discharge of the thermal spring group has decreased from 34.000 m^3/day to

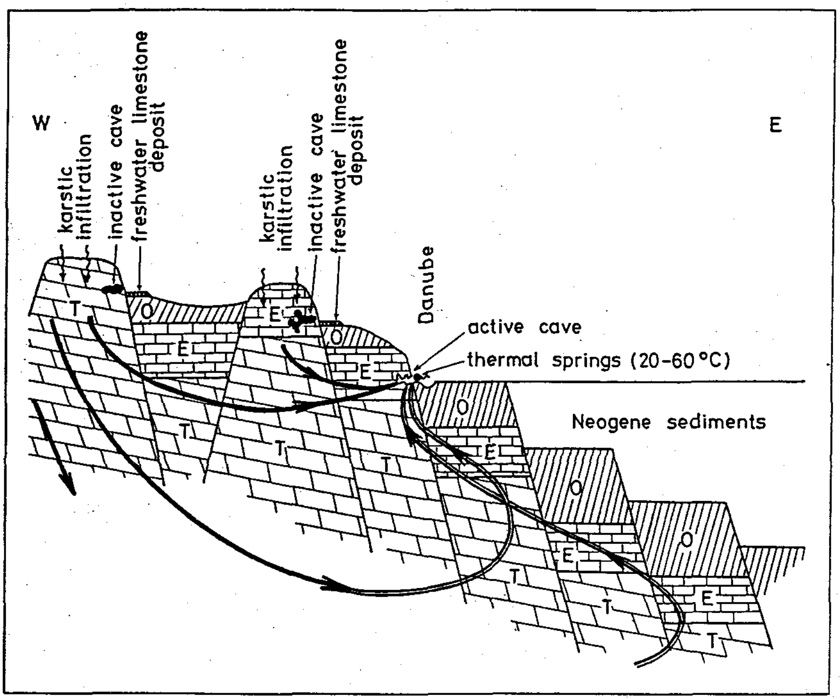

Fig. 1. Scematic profile of the hydrothermal activity of the Buda Hills (after Kovacs and Muller, 1980)

T = Triassic carbonatic formations; E = Eocene carbonatic formations; O = Oligocene clay and silt some 10.000 since the end of the last century; and in the past 40 years, since the beginning of regular water quality investigations, the water temperature has decreased by 4°C accompanied by a decrease of CO_2 and hydrogen carbonate ions. At the same time contaminations of nitrate, ammonium, chloride and sulphate have increased, and coli contamination have also occured. Although certain administrative measures were taken to protect the water quality of the springs, detailed studies on interrelations between the anthropogenous environment and the relict caves - occupying a position

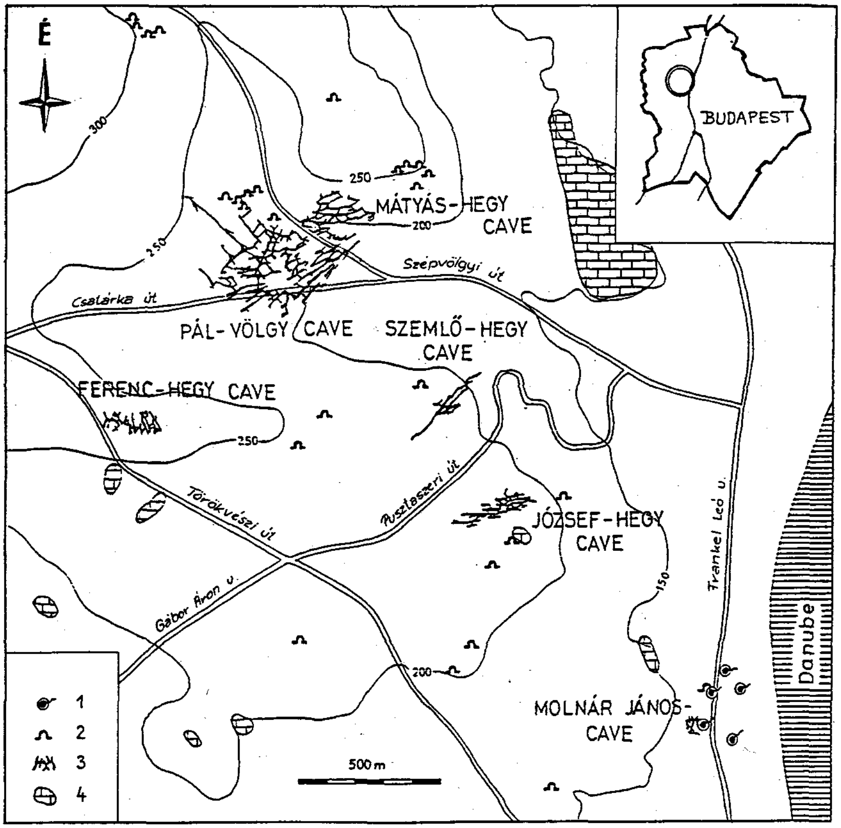

Fig. 2. Thermal karst features of Rozsadomb area
1 = thermal springs; 2 = caves; 3 = increased protected caves; 4 = freshwater limestone deposits

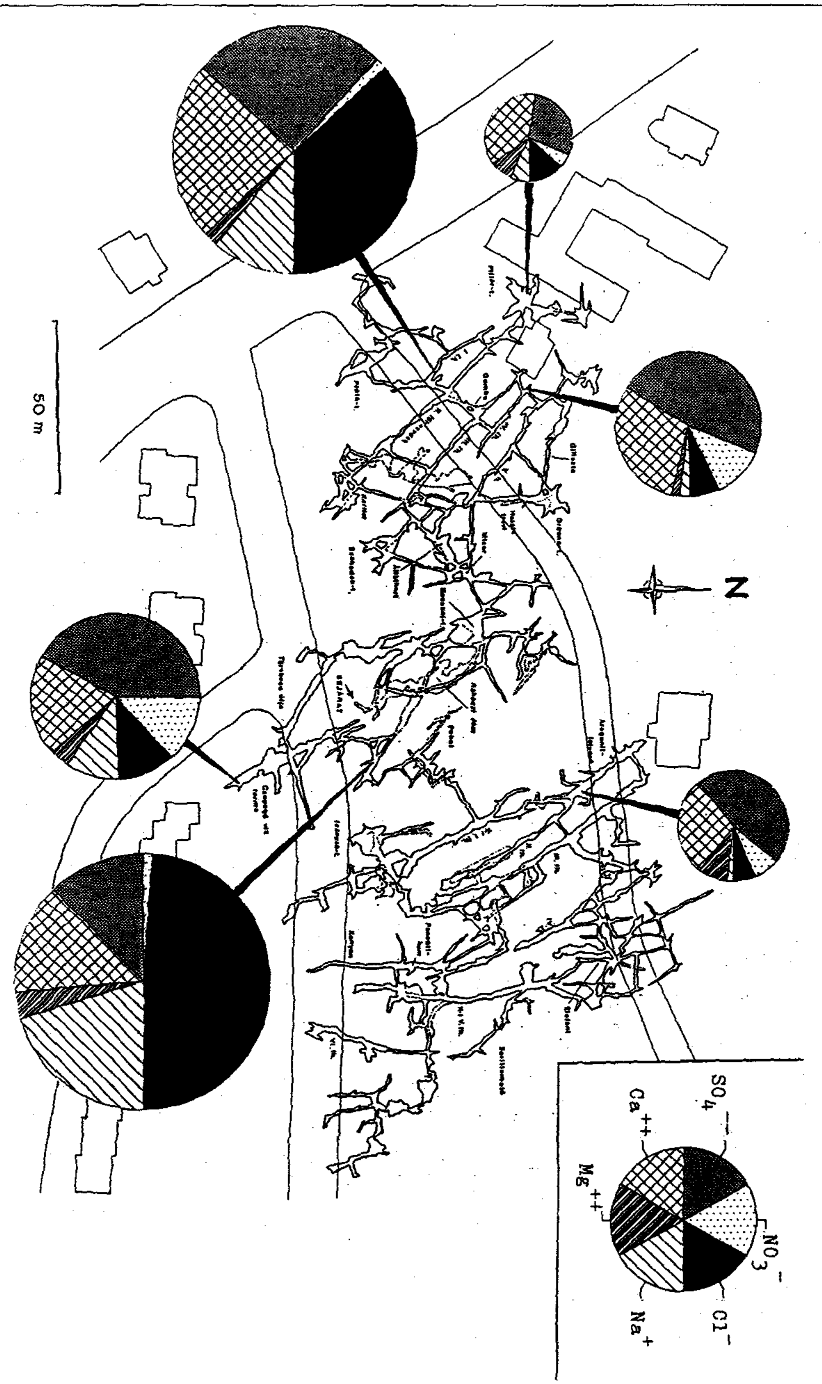

Fig. 3. Chemical composition of dripping water samples in Ferenc-hegy Cave (averages, 1987-1993; the pie areas are proportional with the mg/l values)

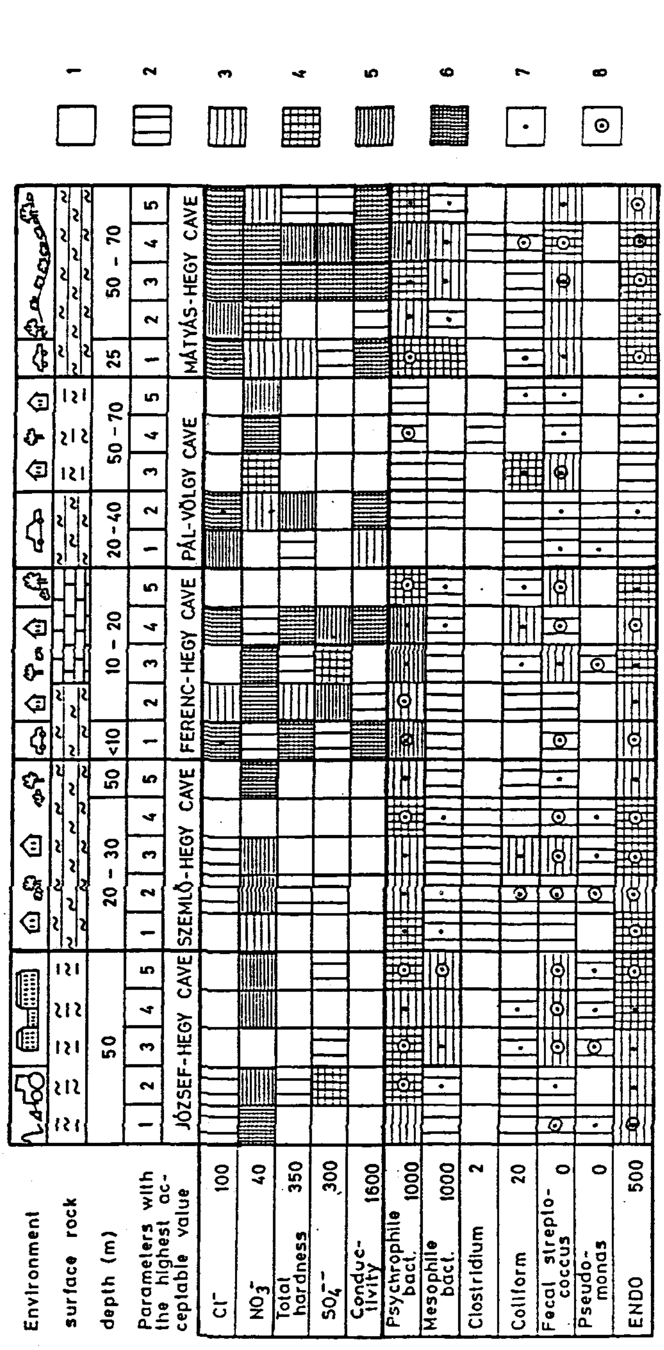

Fig. 4. Stability of contaminations at the different sampling sites (1987-1993)

1-6 = rate of contaminated samples: 1 = 0 % 2 = 1-25 % 3 = 26-50 % 4 = 51-75 % 5 = 76-99 % 6 = 100 %; 7 = occurrence of values exceeding the limit 10-fold; 8 = occurrence of values exceeding the limit 100-fold

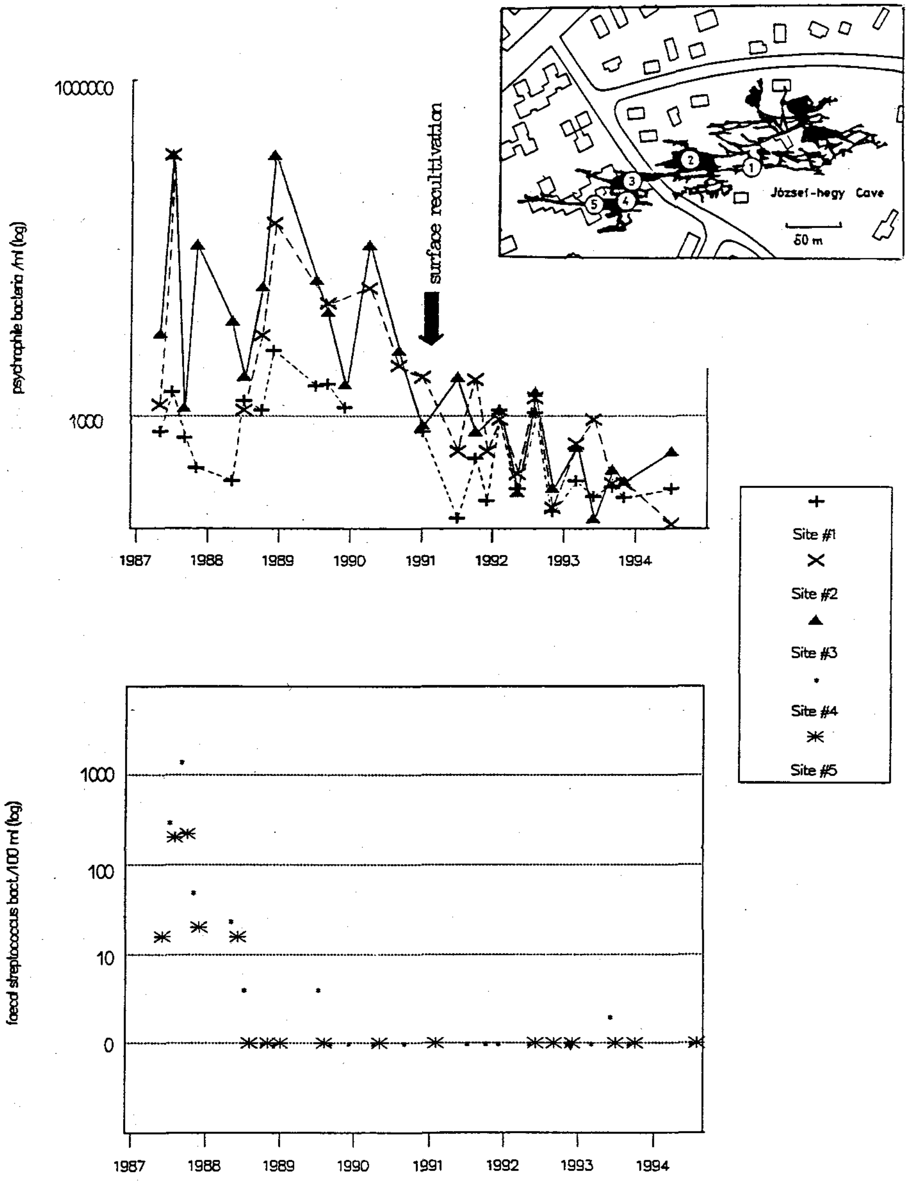

Fig. 5. Time distribution of faecal streptococcus and psychrophile bacteria contamination in dripping water samples of Jozsef-hegy Cave

midway between the surface and the modern springs - were started only ten years ago by at the iniciative of the National Authority for Environment Protection and Nature Conservation.

These studies proved that in the Rozsadomb area the most significant element endangering the caves, and through them the thermal springs, is the qualitative change of infiltrating waters. The maximum 800 m^3/day karstic infiltration of the area represents only about 2 % of the original discharge of the thermal springs. The effect of quantitative changes of this amount is negligable compared to those caused by the drilling of artificial thermal wells tapping the ascending branch of the flow in the northern part of Budapest and by preventive karst water pumping for coal-mine operations at Dorog area at a distance of some 50 kms, which has captured recharge areas from the system.

In 1987 the Institute for Speleology, co-operating with the Budapest Institute for Public Health and Epidemiology, started a comprehensive investigation to determine the extent, origins and areal distribution of contamination of infiltrating waters. This investigation involves seasonal chemical and bacteriological analyses on dripping water samples taken from 55 points of the 5 largest cave systems of the area. Sampling sites were chosen to represent drippings at different depths under surfaces of different rock types and utilisation. The qualification of the samples is based on 15 chemical and 10 bacteriological parameters and compared to the limit values of Hungarian drink water standard.

RESULTS AND CONCLUSIONS OF DRIPPING WATER ANALYSES

In possession of 28 series of analyses for all the permanent drippings and a little fewer for periodical ones, the most important results and recognitions are the following:

1. The different parameters show significant variations, not only with regard to the whole of the region, but also within short distances in the same cave *(Fig. 3.)*. At certain points chemical parameters are rather constant, but the bacteriological ones may vary even a thousand-fold within a short period. Consequently, controlling of dripping water quality requires regular monitoring.

2. All the sampled drippings more or less frequently show bacteriological contamination, and the majority of them chemical contamination too *(Fig. 4.)* regardless of their depth, surface rock and environment. There is no reason to presume that the infiltrating waters of the whole area are of better quality.

3. Chemical contamination of the samples does not always correlate with bacteriological contamination. There are samples with frequent bacteriological contamination that are of drinking water quality from chemical point of view. The explanation is the different sensitiveness of the methods: sewage contami-

nation can be detected by chemical methods up to a dilution of a thousand-fold, while by bacteriological ones up to a million-fold. But, on the other hand, there are samples with stable nitrate contamination (generally considered to reflect sewage impacts) but only rarely with bacteriological contamination; which indicates other possible sources of nitrate. Consequently, neither chemical nor bacteriological analyses alone are suitable for detecting environmental impact.

4. Comparing the results to those of the first two years *(T. BOLNER, TARDY and NÉMEDI, 1989)*, there are no clear trends in changes. Certain parameters at certain points show more favourable values, other parameters or other points less favourable ones. The general condition of infiltrating waters seems to be constant during the past 7 years.

5. Chemical contaminations prove to be rather stable if they occur. Sudden and permanent changes in chemical parameters were usually accompanied by similar changes in intensity of the drippings, which could be interpreted as caused by pipeline damages or repairing of the damage. With respect to chemical parameters, a ten-fold excess over the limiting drinking water standard occurred at three sites and for chloride only. Bacteriological contaminations proved to be more occasional, but more serious also: a 100-fold excess of the limit occurred at 14 sites altogether and for 5 parameters. The endangering effect of relatively low but stable chemical charge, and that of occasional but intense bacteriological charge can be evaluated as equal in the area.

6. Contamination of chloride, that occured with simoultaneously increase of Na-content, and with 10-fold values (up to 3197 mg/l) under roads only, reflects the effect of deicing the roads during winter. As within the past 7 years most of the winters have been mild in Hungary, and no significant salting was needed, the stability of contamination in the drippings drew attention to a considerable deposition of salt in surface sediments. The stable nitrate contamination (up to 265 mg/l) without any significant bacteriological contaminations might be evaluated as the effect of fertilization and other chemical treatment of gardens; while sulphate contamination (up to 925 mg/l) may also be of natural origin, due to weathering of pyrite in the marl-layers covering the limestone bedrock of the caves.

7. Fairly stable bacteriological contamination was found only with respect to *psychrophile* bacteria (up to 600,000/ml) and the ENDO numbers (up to 80,000), which are interpreted as signs of stagnant waters and, a general anthropogenous effect respectively. Direct sewage water infiltration, represented by joint appearence of coliform (up to 8000/100 ml), faecal streptococcus (up to 2000/100 ml) and *clostridium* bacteria (up to 13/40 ml), has been detected at 20 sites, but in 12.1 % of the samples only that refer mostly to casual contaminations. Independent appearence of faecal streptococcus bacteria (up to 1400/100 ml) indicate old faeces effects due to fertilization or leaking

of old septic tanks, that had been constructed before main drainage of the area started.

8. The water quality of drippings in Matyas-hegy cave proves that protective measures on the direct surface of the caves are not enough to avoid contamination. Most of the surface above this cave is a forest belonging to Buda Landscape Protection Area for decades; thus the stable chemical contamination there can originate from outside only, and might be caused by an apparently dry valley being inhabited in its upper section.

9. Time distribution of bacteriological contamination of Jozsef-hegy cave *(Fig. 5.)* is an example of the dangers of disturbing large surfaces by construction work. The two years of stable faecal *streptococcus* contamination in the western part of the cave correlate with the re-gardening of a housing estate built in 1985; while the high level of *psychrophile* bacteria that decreased to quite normal after the re-cultivation of the surface disturbed by foundation pits above the eastern part of the cave, supports the stagnant water origin of this kind of contamination.

All the above features show that current protection involving mostly administrative measures are not sufficient to preserve the sensible equilibrium of the Rozsadomb thermal karst system. The problems identified reflect on the necessary technical-economic steps, the realisation of which might also be promoted by preliminary candidation of the area to the World Heritage in 1993.

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Povzetek

Med antropogenimi površinami madžarske prestolnice in sedanjimi termalnimi izviri je 29 km dolg splet fosilnih termalnih jam. V okviru preučevanja odnosov med urbanim okoljem in podzemeljskim naravnim bogastvom Speleološki inštitut v sodelovanju z budimpeštanskim Inštitutom za javno zdravje in epidemiologijo že od l. 1987 preučuje kvaliteto prenikajoče jamske vode. Redne kemijske in bakteriološke analize vzorcev prenikajoče vode, zajemanih na petih mestih v vsaki izmed petih večjih jam, kažejo pomembne razlike v kvaliteti; toda vsi izmed opazovanih curkov so se pokazali za bolj ali manj pogosto onesnažene glede na kemijske in/ali bakteriološke parametre, ne glede na njihovo globino (10 - 90 m), kamnino na površju (apnenec, lapor, glinasti lapor) ali na okolje (vrt, park, gradbišče, cesta, itd.).

Izmed 25 vzorčevalnih mest jih 23 izkazuje stalno kemijsko onesnaženost, vendar relativno nizkih vrednosti: desetkratni presežek dovoljene količine po standardih za pitno vodo se je pojavil le na 3 mestih, in sicer so presegali dovoljene meje le kloridi (do 3197 mg/l), čemur je vzrok zimsko soljenje cest. Onesnaženje z nitrati (do 265 mg/l) kaže na poškodovano ali pomanjkljivo kanalizacijo ali, kadar ni sočasne bakteriološke kontaminacije, na uporabo kemikalij v vrtovih. Visoka vsebnost sulfatov v nekaterih curkih (do 925 mg/l) je lahko naravnega izvora - razpadanje pirita v laporju nad matično kamnino. Bakteriološke kontaminacije so bolj občasne, a tudi resnejše: stokratno preseganje dovoljene meje se je vsega skupaj pojavilo na 14 mestih pri šestih parametrih. V 12,1 % primerov je bila zasledena neposredna infiltracija odpadnih voda (skupen pojav koliformnih bakterij, fekalnih streptokokov in bakterije *clostridium*). Bolj pogost je bil pojav povečanega števila bakterije *psychrophile* (do 600 000/l), kar odraža stoječe površinske vode; visoko ENDO število kaže splošni antropogeni vpliv, samostojen pojav fekalnih streptokokov (do 1400/100 ml) pa razlagamo z gnojenjem ali puščanjem greznic.