Examples of the human activity impact on quality of vadose zone water in carbonates

JACEK MOTYKA, KAZIMIERZ RÓŻKOWSKI

Faculty of Mining & Geoengineering, University of Mining and Metallurgy, al. Mickiewicza 30, 30-059 Cracow, Poland; E-mail: motyka@uci.agh.edu.pl, kazik@uci.agh.edu.pl

Abstract: Sampling of infiltrating water in cave systems and their chemical composition analyzing allows water quality estimation and often primary identification of pollution source. The investigation was carried out at selected objects localized in southern Poland at Kraków-Częstochowa Upland and Holy Cross Mountains.

Key words: vadose zone, quality of water, carbonates of Upper Jurassic, S Poland

INTRODUCTION

In relation to other regions of Poland, southern part is the most populated and industrialized. Concentrated there are mainly hard coal and metallic ore mining industry, as well as metallurgical industry. The lack of restriction policy on the environment protection field until recently was a reason of increased anthropopressure on its selected elements. As a result of industrialization and settlement predominate spatial pollution sources connected mainly with air pollution by sulfur and nitrogen oxides. However disordered water management cause significant problems as well and under conditions of high population has negative influence on groundwater and surface water quality. It results in increased nitrate concentrations in water environment. Emission of sulfur and nitrogen oxides to the atmosphere significantly decreases precipitation reaction. The phenomenon commonly present on highly industrialized areas is known as acid rain. In southern Poland lots of exposed outcrops are built with carbonates, what favors acid rain neutralization, but simultaneously forms calcium sulfate, which is better soluble than calcium carbonate. Acid rain buffering on carbonate influences increase of total hardness as well as sulfate concentration of infiltrating water. As a result water with increased sulfates concentration is observed within aeration zone (HEJMANOWSKI & KLECZKOWSKI, 1994; MOTYKA ET AL., 2002). The zone of increased sulfate concentrations is slowly shifting downward.

At the background of groundwater spatial pollution sources are observed varied local, linear and point pollution sources, as dumping sites, roads, petrol stations, etc. Pollution migration investigation in karst-fissure aquifers is very effective in cave systems. The paper presents examples of different local pollution sources influence on water quality in caves of vadose zone.

Scientific paper

RESULTS AND DISCUSSION

Smocza Jama Cave (Cracow)

Smocza Jama cave is developed in a transition zone, within small, isolated horst, build up by Upper Jurassic limestone (HEFLIK & MATL, 1991). The horst called Wawel Hill adjoining to Wisła River was primary a dry, elevated place surrounded by marshes. It was so convenient defense point and therefore already at IX and X century Wawel Hill was densely built over. Since the beginning of XI century it became a polish capital and a center of religious authorities. At present it's a monument of polish history and culture frequently visited by tourists.
Investigation of water quality within Smocza Jama Cave took place in the years 1995 – 1998. At the part available to visitors were stated two drippings (SJ D-1, SJ D-2; Fig. 1), sampled at 1995 (point SJ D-1) and at 1998 (points SJ D-1, SJ D-2). At the part not open to tourism were sampled four pools (SJ-1, SJ-2, SJ-3, SJ-4) connected directly to groundwater of Wawel Hill. Generally six sampling series were realized at the part with pools, however difficult access to narrow and twisted parts of the cave didn't allow to sample each time all of them.

Figure 1. Plan of Smocza Jama Cave. 1 –brickwork, 2 – entrance, 3 – sampled dripping, 4 – sampled pool.

Electrolytic conductivity, pH and temperature of pool water as well as air temperature outside and inside of the cave were determined at field. Chemical composition of sampled water was determined at the laboratory of Department of Hydrogeology and Water Protection of University of Mining and Metallurgy at Cracow.
Chemical composition of water originating from pools and drippings unequivocally proves its pollution by human activities. At the pools, which are a part of groundwater flow towards

Wisła River, pollutants partly originate from adjacent areas of dense building. These are mainly leakage from untight sewage system and made ground rinsing, likely structured partly with municipal wastes. On the other hand precipitation infiltration through made ground of Wawel Hill forms chemical composition of water dripping in Smocza Jama Cave. Probably a certain share has leakage from untight sewage system of the Hill. Influence of domestic sewage and possibly municipal wastes on dripping water chemical composition indicates increased concentration of nitrates ranging from 18,6 to 280,4 mg/l, potassium in range from 31,7 to 132,5 mg/l, phosphorus (<0,1 – 1,74 mg/l) and boron (0,18 – 1,00 mg/l). J. Kogovšek (1997) described similar case from Postojnska Jama, indicating leaky cesspool of a former military object as a pollution source. According to Kleczkowski (1977) a certain share of Wawel Hill groundwater and adequately of pools observed in Smocza Jama Cave can originate from higher mineralized water ascending from deeper parts of this small horst.

Chelosiowa Jama Cave

Chelosiowa Jama Cave opens in an abandoned quarry localized within middle and Upper Devonian limestone being a part of Kielce Anticline. Investigation carried out in Chelosiowa Jama Cave included chemical composition of drippings (points CH-1, CH-2, CH-3, CH-5) as well as one water pool (CH-4; Fig. 2). The sampling lasted since X.1996 until VIII.1998.

Figure 2. Plan of Chelosiowa Jama Cave. 1 – entrance, 2 – sampled dripping, 3 – sampled pool.

Until 1997 on a surface over the Chelosiowa Jama Cave existed a factory producing cooling fluid and accumulator electrolyte. Out-of-control infiltration of unknown liquid wastes from the factory to Devonian limestone has considerable influence on chemical composition of

Chelosiowa Jama Cave groundwater. Predominate calcium and sulfate ions what can indicate process of acidic liquid wastes buffering on Devonian limestone. At points CH-2 and CH-3 maximal sulfate concentrations respectively exceeds 670 and 800 mg/l while calcium concentration 270 and 260 mg/l. The nature of infiltrating pollutants influences increased concentrations of specific minor elements in sampled water, such as Al (<0,06 – 0,28 mg/l), Fe (<0,01 – 0,26 mg/l), Mn (<0,002 – 0,170 mg/l), as well as Cu (sampling points CH-1, CH-2, CH-3) in range from 0,007 to 0,033 mg/l, Cr (sampling point CH-4) ranging from 0,012 to 0,056 mg/l, Pb (points CH-2, CH-4) in range from 0,090 to 0,095 mg/l, Ti (point CH-4) respectively 0,020 to 0,027 mg/l and V (points CH-3, CH-4) from 0,014 to 0,015 mg/l. Respectively high concentrations of Cl (9,08 – 91,8 mg/l), Na (14,1 – 35,7 mg/l), K (4,35 – 105,9 mg/l) ions and minor elements: B (0,06 – 2,59 mg/l), Li (<0,01 – 0,053 mg/l) and P (<0,1 – 0,18 mg/l) additionally indicate eluate infiltration from various kind of wastes, including municipal, stored in an abandoned quarry without license and any kind of protection.

CONCLUSIONS

Investigation of groundwater chemical composition from drippings and water pools within cave systems enables improvement of knowledge in field of vadose zone function in groundwater quality formation processes. Moreover enables identification of surface pollution sources even not known before. Results of investigation from Smocza Jama Cave revealed influence of compact urban settlement on water quality within vadose and shallow phreatic zone. On the other hand chemical composition of drippings and pool from Chelosiowa Jama Cave located in Holy Cross Mountains forms under the influence of liquid wastes infiltration from not existing presently factory, which produced cooling fluid and accumulator electrolyte until 1997 as well as effluents from varied waste dumping site, including municipal wastes, deposited illegally over the cave.

Acknowledgements

This work was supported by the University of Mining and Metallurgy – project number 10.10.100.677.

REFERENCES

HEJMANOWSKI, J., KLECZKOWSKI, A. S. (1994): Preliminary investigations of contaminants transport in vadose zone of marls and Cretaceous limestones of the Miechów trough (GZWP 409) (in Polish). *Methodical principles of groundwater protection.*; KBN - Project: 9 0615 91 01, pp. 97-108, Kraków.

HEFLIK, W., MATL, K. (1991): Geological characteristic of Smocza Jama cave on Wawel (in Polish). *Studia do Dziejów Wawelu.*; Vol. 5, pp. 29-53, Kraków.

KLECZKOWSKI, A. S. (1977) - Hydrogeological conditions of the Wawel Hill in Cracow (in polish). *Bull. Of Geology.*; Vol. 21, pp. 153-175, Warszawa.

KOGOVŠEK, J. (1997): Pollution transport in the vadose zone: An example from Postojnska jama - Slovenia. In: Karst Waters & Environmental Impacts. *Proceedings 5th International Symposium and Field Seminar on Karst Waters and Environmental Impacts, Antalya, Turkey, 10 – 20 September 1995.*; Gunay, G., Johnson, A. I. (eds.), Balkema, Rotterdam.

MOTYKA, J., RÓŻKOWSKI, K., SIKORA, W., GOC, J. (2002): Influence of unsaturated zone in Upper Jurassic limestones on the chemistry of groundwater. Ojców National Park, southern Poland (in polish). *PTG Bull.*; Vol. 404, pp. 123-144, Warszawa.