W O R K S H O P

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Water Problems in Karst Mining Environment
An approach

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INTRODUCTION

It is impossible to synthesize a topic such as *Water Problems in Karst Mining Environment* in the short content of a paper or a lecture. This matter would require hundreds and hundreds of pages and many hours of dissertation.

In this condition I only intend to present some interesting aspects in this topic published in the lasts issues of the IMWA Journal: *Mine Water and the Environment* (formerly *International Journal of Mine Water*), adding some personal experience.

ORIGIN OF KARST MINE WATER

The quantification of mine water by source is complex due to the complexity of the karst-mine environment, and the parameters changes occurring during the groundwater flow.

Many studies has been published about technologies employed to establish the different sources of mine water in karst dominium, and also related to the balance between such waters.

I wish summarize the Zhou et al. (1994) paper related to the employment of environmental isotope to define the water origin in Pingdingshan Coal Mining Area (China).

The authors have study systematically the isotopes values of rainwater, surface water and groundwater and have applied hydrogeological techniques to ascertain the following:

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- groundwater formation, distribution and migration laws;
- recharge source of mine water and its mechanism; and
- differentiation of the different water inflow in mine water and determination of ratio of recent water.

Groundwater recharge area is mainly the Cambrian limestone through rainfall, together with the seepage of northern trunk canal and Zhanhe River.

In order to establish the migration and distribution laws, together with the recharge source of mine ground water, the laboratory analysis included de determination of stable oxyhydrogen isotope fraction (δD, δ^{18}O) and radiactive isotope decay (tritium).

The authors concluded that the environmental isotopic hydrogeological technique is a feasible method to solve mine hydrogeological problems. It is a desirable tool for studing the formation, the mechanism of mixing, the movement rules, the real flow velocity and the age of groundwater. In addition, satisfactory results have been obtained in studying deep circulation karst water in mines.

We have published (Mulenga et al. 1992) the technologies employed to establish the different sources and rates of water inflow in Konkola Mine (Zambia), as a part of an integrated hydrogeological research program conducted in this mine one of the wettest mines in the world.

The investigation methodologies employed include: hydrochemical investigations, isotopic content (tritium), bacteriological and microbiological studies of the surface and mine water environment of natural or anthropogenic origins.

The mine is located in a complex multilayer aquifer system, where the ore body is sandwiched between major aquifers with karstified carbonate rocks in the hangingwall and with high potential of surface inflow infiltrating into the mine.

The hydrogeological tracers was used to determine the origin and flow pattern of mine water inflow. Employing dissolved ions as hydrochemical tracers can take to approaches: either using the natural water constituents or added chemical compounds. The natural constituents approach is based on the understanding that dissolved ions in water of different origin will reflect the different geochemistry. Whilst adding chemical compound to a body of water provides the possibility of tracing the flow path. Xanthates, as anthropogenic tracer proved a direct link between the Tailings Dam and the mine water. Aerobic germs permitted to establish the water connection with high surface water infiltration areas. Coliforms was determined as the most resistant to biodegradation, followed by *Escherichia coli*, and least *Streptococcus*. Water temperature was defined as one of the most useful physical parameters of water that can be used as a tracer.

Water radioactive tracers can be natural unstable isotope existing in surface or underground waters (such as ^{14}C, or other unstable isotope added into the water for research purposes (as ^{131}I and ^{3}H) or present in water mainly as consequence of the anthropogenic activity (as ^{3}H). These tracers can be employed to establish the hydrologic connection between surface-underground water, or between different aquifers, or between underground-surface waters. Also the radioactive isotope can be used to date the water.

In Konkola Mine following numerical method through an iterative tangential in advance partial derivative (100 maximum), applied to non linear systems, solving the equation systems by the Newton method was quantified the water balance by source for each mine shaft and for the total mine discharge (43 % surface water and 57 % old water (aquifers s.str.)).

As a very especial tracer we have employed with success at Reocin Mine (Cantabria, Spain) the biological content of the water mine inflow.

KARST WATER QUALITY AFFECTED BY MINING OPERATIONS

The mining drainage can affect the natural quality of karstic aquifers due to different processes. Some detailed studies can be hunt up in the bibliography published by IMWA. Between this I summarize the paper published by Gajowiec and Witkowsky (1993), related to the Trzebionka Mine (Southern Poland).

Fissured-karstic basin of the Triassic carbonatic series in the Chrzanow region is a very important source of potable water for the great urban and industrial agglomeration of the Upper Silesian Coal Basin. This multilayered aquifer is subject to a strong anthropogenic pressure with leads to the degradation of water quality and depletion of water reserves.

The hydrogeological basin, extended below about 310 km^2, is drained through the Zn-Pb ores mine Trzebionka and probably also by the Janina and Jaworzno coal mines, together with intakes of Katowice town and individual wells. The total amount of pumped water is 3714-3914 m^3/h.

Due to the intensive drainage a large an irregular cone of depression has been formed with the maximum dept of water level 240 m below the ground water level. The possible hydraulic flow velocities has been calculated: 1.5 km/year in zones of low hydraulic gradient, till 20 km/year in the zones of high gradient.

According with isotopic investigation the maximum time of flow in the karstic-fissurated system is several years. According with the above data it may be assumed that possible pollution may be transported, due to high speed and low filtering ability of fissures at large distance in relatively short time.

The chemistry of groundwater occurring in the Triassic carbonate aquifer is variable. Most frequently the water is of HCO_3-Ca and HCO_3-Ca-Mg types with range of total dissolved solids from 226 to 940 mg/l, with an average of 437 mg/l.

High content of Pb in water from Trzebionka mine is regarded as particularly dangerous for water users and the natural environment. Highest concentration periodically reaches 8.0 mg per litter, above the limited admitted by the standard for potable water. Increased contents of Zn, Cd and Sb ions in mine water is also noteworthy. As a result of anthropogenic pollution the concentrations in other elements has been established. Appreciation of changes of ground water quality in Chrzanow region in respect of time has been established using the base of the comparison of water chemical analysis series from 1956-1959 and 1986-1989 shown a shift in direction of higher concentrations, mainly in the area of the Trzebionka mine.

In this case the waters from mines contain higher amounts of toxic and environmentally polluting heavy metals, which is caused by contacts with ore outcrops and pollution originated by mining and extraction processes. Underground water in contact with sulphides, oxidizing then rather easily dissolved heavy metals. At the later stage, precipitation of such metals occurs when waters with leached metals get in contact with carbonate rocks. I have observed the same process at Reocin Mine (Cantabria, Spain), a Zn underground mine with complex sulphides in dolomite host rocks.

In other sense I have find very frequently relative high NO_3^- content related with the explosives employed in bore-holes blasting.

MINE WATER DRAINAGE IN KARST ENVIRONMENT

Without any doubt one typical characteristics of mine dewatering in karst environment is related with the frequently large quantities of water inflow both as permanent yield and as suddenly irruptions.

Many problems in such mines are consequence of the water risks and the dewatering costs.

Mine workings below the piezometric level require dewatering processes which produce induced flow from surrounding rock mass towards the mining excavations creating extensive cone of depression.

We have published (Fernández Rubio & Fernández Lorca, 1993) a revision of the typology of dewatering evolution yield in mines, several of then in karst condition.

The quantity of mine water inflow to underground working will depend upon transmissibility of the formations, dimensions of the fractures and cavities, hydraulic head, thickness and position of the protective layers, etc.

MINING SUBSIDENCE IN KARST DUE TO MINE DEWATERING

Mining activities can provoke subsidence and collapse processes in two ways. The first one are related with mining opening roof collapse mainly where caving exploitation methods are employed. Such process can occur with any type of host rocks. The second group are related with natural solution opening, in karst dominium, and occur both with dewatering processes or water irruption. In this paper we only will considerer the second one, as specific of mining in karst.

When a full of water solution cavity is affected by the mining drainage, the equilibrium condition can be change in several ways. There are the possibility of solifluction of the dissolution residual clay (*terra rossa*), there are also the possibility of a vacuum effect (mainly when the cavity is drained suddenly due to the unblocked of some karst conduct).

Such cavity collapse are frequently described in many papers, related to mine operations in karst condition in Canada, China, South Africa, Spain, Poland, ...

In any case China appears as a country with many subsidence in mining areas due to dewatering processes. Between the different papers published by IMWA I select as more interested, the one which author is Yu (1994). Carbonate rocks occupied in China 3.25 million km^2, including bare karst of 1,25 million km^2, and the rest belongs to the covered and buried karst. Many mines (coal, iron, copper, aluminium, ...) are located in this material or in its vicinity. The majority of the well-know water-abundant deposits with mine water inflow rate with more than 1 m^3 per second are in karst aquifer where subsidence frequently occur. In this country a total of 30005 subsidence was scattered dominantly in karst aquifer mines areas.

In China has been proved that pumping, dewatering, drainage and water inrush in the karst mining environment set of surface subsidence larger in scale, greater in number, and longer in duration. Up to now 94 mining areas have been located with the occurrences of surface subsidence. According with Yu (1994) in 34 mine areas, there have been 23,941 subsidence scattered in the Palaeozoic coalfields and in the intrusive contact-polymetallic mining areas.

Surface subsidence can implicate dangers as follows: to affect the environments; to modify the hydrogeological and engineering geological conditions; to increase the amount of mine water inflows; to provoke water and mud irruptions; to dry up the wells and springs in the surrounding area; to reduce the mine production and safety; to produce injuries and deaths in human population and livestock; to damage buildings, bridges, roads, railways, ...

Some significant effects are described by Yu (1994): in Fankou area the volume of subsidence amount up to 5.50 million cubic meters, with an influence area of over 8.30 million m^2. Mine water irruption contributed with 2 million m^3 of mud; 70,000 m^2 of buildings area have been damaged, 15 km of roads and 45 km of railways destroyed, ...

In addition surface subsidence provided ways to surface and underground water inflow. Yu (1994) described in Sinding mine area inrushes up to 24 m^3 per second, causing flooding of mines three times through subsidence pits of river bed.

Surface subsidence results in surface soil erosion, and inflows of mud and sand to mines through subsidence pits.
Mine subsidence can be predicted on the base of a good knowledge of karst processes in the area affected by the mine drainage. In some cases is possible to determine some areas with more probability, according with the geological conditions and supported by geophysical prospecting (electric, seismic and gravity methods), when are located the presence of dissolution openings.

Frequently the surface subsidence occurs where shallow karst is intensely developed below a cover coverage of not karstified soft material below 30-50 m thickness. The process is usually associated with heavy rains and intensive underground drainage. We have investigated the subsidence occurred in Vazante Mine (Minas Gerais, Brazil), a underground zinc mine (willemite mineralization in carbonaceous rocks), where after an substantial increase of pumping dewatering rate, the piezometric levels was not affected temporary in an restricted area where take place an suddenly water level drop simultaneous with a 17 m deep collapse affecting seriously the electric transformer area. Once mining groundwater table falls, or the hydraulic gradient raise, the surface subsidences usually take place abruptly. For example Yu (1994) described that in the Shaikoushan Mine (Hunan, China), while the drainage was 588 m^3 per hour, 20 surface subsidence take occurred and 202 as mine drainage reached 1100 m^3 per hour.

In the Belhatov Mine (Poland) an large open pit coal mine, cover by glacial deposits, some similar subsidence occur due to the mine drainage affecting drilling rigs, drainage channels, ...

Finding the dominant cause of subsidence is possible to eliminate or to reduce the subsidence occurrence and development. According with Yu (1994) and with our personal experience, for preventing surface subsidences in karst water-abundant deposits, the key measure is to control the intensity of mine dewatering and drainage. Always it is better to drain karstic water mildly than to drain intensely with deep draw-down, in order to avoid the rapidly declining groundwater table which results in a lot of subsidences. In underground mines the measure to prospects in advance should be taken so as to seal off water invasion points in time, and turn off the situation of water invasion into man-controlled discharge.

As the subsidence reaches the measure to cover the subsidence pits, with backfilling, intercepting streams and diversion of river channels should be taken in order to decrease the rate of groundwater inflow. In Enkou mine area (Southern China), the approaches of back filling and covering subsidence pits, grouting screen to cut off karst groundwater flows of run-off zone, cementing channels and the modification of stream paths have been adopted and proved to be considerably effective in both decreasing the groundwater influx to mines through subsidence and controlling the development of further collapsing.

Generally the mine water infiltration increases with increased mining activity mainly if the effects of subsidence become greater.

FINAL REMARK

This paper shows some examples taken between the variability of mine water problems when mining operations are located in karstified areas. The hydrogeological, environmental and economic repercussions require to adopt appropriated management strategies to reduce the different impacts of mining operations

BIBLIOGRAPHY

Fernández-Rubio, R. & Fernández Lorca, D. 1993. Mine water drainage. *Mine Water and the Environment*. Vol 12, pp 107-130.

Gajowiec, B. & Witkowski, A. 1993. Impact of lead/zinc ore mining on groundwater quality in Trzebionka Mine (Southern Poland). *Mine Water and the Environment*. Vol 12, pp 1-10.

Mulenga, S.C., Fernández-Rubio, R., León, A. & Baquero, J.C. 1992. Estimation of quantitative water inflow from different sources in Konkola Mine, Zambia. *Mine Water and the Environment*. Vol 11, No 4, pp 1-22.

Yu, P. 1994. Surface subsidence in the karst mining area in China. *Mine Water and the Environment*. Vol 13, No 2, pp 21-26.

Zhou, J., Sun, J. & Zhang, f. 1994. Origin of mine water by using environmental isotope technique in water-logged coal mines, Pingdingshan, China. *Mine Water and the Environment*. Vol 12, pp 63-70.