Water Quality Control Related to Abandoning of Deep Bauxite Mines

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ABSTRACT

The Nyirád Mines in the Transdanubian Mountains have been badly affected by dangerous water inrushes in the past. These mines have been abandoned and were refilled by the end of 1990. Flooding of mining areas and deposits previously protected by the preventive dewatering has started immediately. During the past 30 years a regional water supply system providing drinking water for about 1.5 million people has been constructed utilizing the subterranean water. Water quality protection became a problem of primary importance. The task was especially difficult because there was no example to follow and the time span provided for design and implementation was not more than 14 months.

The Company has charged many research institutes with various design tasks, and finally the Research Institute of Water Resource Management completed the design of measured components and measuring sequence of the chemistry and bacteriology monitoring system.

The recharge process, the effect of the absence of water release into the surface water courses, as well as expected date of water cycle balance restoration were also investigated.

This paper presents experience obtained during the past four years at Nyirád water release and intends to provide useful information to similar projects.

INTRODUCTION

The Hungarian Government decided to close the bauxite mines of the Nyirád area in April 20, 1989. The reason for the decision was to protect the famous spa of Héviz Lake, located 27 km from Nyirád. During past decades the whole area of the Transdanubian Mountains was influenced by the dewatering effect of the ore mining.

71% of the total water transport was directly related to the mining, and the active dewatering of the Nyirád area contributed 23 % percent out of the above. Water supply of the largest unit of the Transdanubian Mountains, the Bakony was strongly affected by this dewatering.

Figure 1 shows the karst water map of the Western side of the Bakony Mountain. Water protection and depression unchanged since 1983 was presented at the 2nd IMWA

Congress [1]. An irregularly shaped depression zone extending more than 50 km is formed on the Northeastern side of the mountain. The zone forms one single hydraulic unit with the surface layers and represents about 120 m depression of the original karst water level. The boundaries of the zone are not known exactly because of the superimposing effects of dewatering and the distribution of the monitoring sites. Depth point is 60 mAf.

A pumping requirement of 220 m^3/min of the quasi permanent condition is equal to the value of dynamic supply, and based on the above assumption the supply area is estimated to be 360 km^2 while the mining area was only 16 km^2.

The regional water supply system of 60 m^3/min nominal capacity partly compensated for the damages caused by dewatering of an oversized area.

Water quality protection after abandoning the mining consists of two tasks:

- The boundaries of the protection area at the surface required planning together with a limitation on water consumption;

- Contaminants within flooded mining areas as well as the danger of polluting drinking water required estimation and preventive protection measures should be determined.

The open surface, an uncovered or partially covered water source is sensitive to contamination and is therefore very vulnerable. The wells are deepened to the crossings of expansion rift zones which are operating as advance headings [2].

There was no risk of contamination at lowered water levels. Most of the supply arrived from the unattached karst regions of Bakony Mountain. The contamination carried by leakage represented no danger at all in comparison to the huge amount of water transported. The open water system is much more vulnerable. Taking into account the 60 m^3/min capacity the water supply arrives from a 9-10 km surrounding of the wells, and at the actual lower (30 m^3/min) water consumption from an even closer region. The outside contamination is reaching the continuously raising water level earlier, and what is even worse: it is transported rapidly to the wells through the open rifts.

The Research Institute of Water Resource Management was hired to design the surface protection area. At the boundaries 1, 5, and 50 years boundary limits were computed using contaminant transport lags. The boundary limits basically agreed well with the surface boundary of the hydrogeological protection area.

Inside of the one year boundary a proposal to ban all sources of contamination was proposed. All activities within this area should be restricted to the work of the water plant.

Activities within the five years boundary are restricted to those allowed by the Environment Protection Agency. Such activities should not produce pollution, should include Class I waste water cleaning, agriculture free of chemicals, large scale stock breeding is not allowed, it is obligatory to stop all industrial or other concentrated sources of pollution, and it is obligatory to remove all sorts of waste.

Experts investigating the effects of mining surveyed the contamination sources remaining in the abandoned area as well as other possible sources and assessed their hazards. In order to perform the above task the experts surveyed the mines to be abandoned, horizontal and vertical distribution of loosened zones, the headings remaining passable (the length of these reached 26 km), the refuse surrounding the bauxite ore, and the chemical processes of rocks contacting fresh air due to the caving.

It is reassuring that the neighbouring roof is coloured clay and dolomite foot is found in the higher roof layers. The carbonate rocks do not dissolve at neutral pH values. The bauxite itself does not dissolve either, its dust will settle easily and the rocks containing fine cracks will provide sufficient filtering. Higher attention was be paid however to the coal containing clay roof. The pyrite containing sediment decomposed in air as indicated by the acidic character of the sweat water. Based on laboratory tests the National Institute of Health predicted 0.13 mg/l Fe concentration of drinking water wells if a 120,000 m^2 by 10 m thickness pyrite containing clay was gradually flooded. Taking into account the prolonged hold-up process they considered the probability of concentrations reaching 0.2 mg/l in some wells.

The water quality was better than originally expected and the concentration of said component remained under 0.1 mg/l.

The favourable change of the water quality is attributed to the fact that the reducing power of the sweat is ineffective in dolomite filtered wells located several hundred meters from the ripping because the pH value of water flow will soon reach the neutral value in a carbonate rock.

Due to the above reasons it is not likely to have higher concentrations of SO_4, Mn, Al, Ca+Mg measured as CaO although the laboratory soaking tests indicated concentration increase. Acceptable SO_4 concentration and hardness were observed at some wells, and the mixed water quality was not impaired.

In order to estimate the remaining contamination all materials used in mining and actually transported into the mine were assessed.

The time provided for abandoning the mine was six month. All the removable equipment and materials (props, supports, mechanical and electrical equipment, cables) were taken out, and fuel as well as oil contaminated soil were removed.

Category I

Oil and oil derivatives;
Ammonia;
Bacteria;
High concentration of elements and compounds dissolved from refuse and ore (Fe, Mn, NH_4, hardness, KOI, H_2S).

Category II

Wood;
Steel structures, piping;
Concrete;
Plastics insoluble in water.

In Category I 40 % of the motor oils is considered waste, the rest is taken out with the produced ore. 1 % of diesel fuel is considered waste.

Oil contamination is restricted to the working tunnels. 80 % effectiveness is expected by removing the bottom material considered necessary by visual observation. Bituminous emulsion used for dust control of tunnels did not dissolve during the laboratory tests, therefore it was not removed.

The experts considered a 10 m thick loosened zone over the caving, and considered mobilization of oil derivatives remaining in the free volume of 15 % during one year. An average concentration of 0.055 mg/l is computed from the above assumptions, while in a single case 1 mg/l concentration was observed.

Results of the last three years are much better. Oil content of drinking water wells exceeded the 0.1 mg/l allowable (standard) limit in five cases only. These cases were observed during the first two months of the flooding, and only for wells located few hundred m from the mining area.

Many experts are convinced about the strong binding of oil on the surface of minerals, especially of clay minerals because of the surface potential conditions. Other experts predict the decomposition of oil derivatives in five years.

Since in Hungary the disinfection of drinking water is done with chlorine gas and the chlorinated hydrocarbons have carcinogenic effects and have unpleasant odor, it is of utmost importance to give absolutely oil free water into the network.

The continuous fluorescence monitoring indicated oil contamination in many cases. The laboratory tests showed other types of hydrocarbons, which are considered to be the products of rotting of mine timber. Their presence and their minute concentration cannot be determined by conventional chemical analysis. Toxicology test of water exceeding the fluorescence limit was negative. Medical experts also considered ammonia and bacteria pollution, but the total load in the mined cleaned before closing was probably significantly less than expected, because the actual values were much less than the predicted 100-200/ml, and we suppose these contaminations came from other sources and not from the mine.

Category II required forecasting decay rate of all organic matter, actually mine timber. Experts considered 50 % of the original timber amount to enter into the water by decay, and assumed 20 % yearly decay rate, which was decreased to 10 % at pyrite containing locations. During the first year of flooding biochemical (permanganate) oxygen requirement (KOI_{ps}) of the water was estimated and found satisfactory (less than 10 mg/l). Expert opinions differ about wether the steel structures/piping left in the mine will damage water quality or not.

Potentially mobilized contaminants originating from older, higher mining levels (operated before the LHD technology) have also been considered. Oil contamination from these levels is not likely. Otherwise the situation was considered to be similar to the above. Experts predicted different filling up process, but all estimations gave slower filling than the actual.

In spite of the unknown mobility of contaminants and the lack of laboratory experiments confirming estimations the experts made a deliberate mistake in favor of safety.

Water quality monitoring system

A new task was assigned to the remote measuring and control centre serving both dewatering and drinking water supply at the time of mining: continuous water quality control and the possibility of immediate intervention.

Measurement units of drinking water pits are set up for remote sensing and measuring, and allow for computer data collection and processing.

The units measure and record:

- Oil content (FLUORITEST fluorescence tester),
- Conductivity (AQUADAT),
- Turbidity (NEPHELON-3), and
- Temperature of water.

The control circuit automatically stops water entering into the manifold if the appropriate quality limits are exceeded. In such cases samples are taken for chemical analysis and the operation of the well is closed.

A Computer centre records continous measurement data (including technical data) every two minutes. Operating conditions can be retrieved at any time. In order to promote future investigations of the authorities or pragmatic testing daily data is stored on floppy disks. Data processing software can statistically evaluate and construct trends of data covering any time span.

As well as the above tests, monitoring samples are taken by the Health Authority at each location regularly for chemical and bacteriology testing. At the begining samples were taken weekly, then every second week. Now samples are taken monthly.

Water supply capacity of 120 m^3/min provides 100 % safety reserve. This was selected instead of a multicomponent cleaning purification plant and this decision has been confirmed in practice. Up to now there has been no operating condition requiring use of reserves.

Besides the physical cleaning of abandoned mines as described above the Water Management Authority required so called mine irrigation. Main working tunnels were connected through drifts with the irrigation shafts and flooding water was pumped out. This high hardness water contained high amount of iron, sulphate, and oil, but an irrigation of up to 15 m^3/min resulted in continous improvement of water quality. Today the irrigation wells are only operated before sampling.

Water supply balance

This non permanent process will hold until the drinking water delivery and dewatering of other mines in the area is balanced by the dynamic supply. More than 100 out of the 200 karst monitoring sites of the mountain are located within this area. Future water levels can be reliably estimated from the data series provided by these sites. Drying up of karst springs was caused by the decrease in the water level. Once the pressure conditions become identical to the original the springs will flow again.

Undisturbed flow of the catchment area of Balaton is estimated to 144 m^3/min capacity. As a result of 65 m^3/min taken out of this capacity springs of three brooks dried out, and one was strongly affected.

One brook was damaged however by the ceasing of mine dewatering. The trout lake cannot operate until the natural water supply will resume.

The same problems exist on the other side of catchment area of the Danube river due to the missing 100-130 m^3/min pumped capacity.

The zero line of depression moves towards the centre of the areas as the filling up process takes place. The balance is quickly reached at the boundaries. For example the capacity of the spring supplying the Malom Lake of Tapolca increased to 1 m^3/min during the first two years, and has reached 7-9 m^3/min capacity by the end of the third year, and will surely approach the original 27 m^3/min capacity very soon.

CONCLUSIONS

The water supply capacity of the Nyirád Basin is determined by the open tectonic zones of the dolomitic underlying rock. Water level changes extending to a large area can bring concentrated contaminants into the flow zone and the deep karst is becoming more vulnerable.

With respect to the chemical processes influencing water quality it is very important to size up all material left at the site after mining. The rate of filling up depends on the supply conditions of the hydrogeological unit. Comparison of predicted and actual conditions is also important factor in water quality determination. Interventions are required in order to provide safety of water supply.

Water users having temporary permission on the temporarily ceased water courses have to face losses therefore knowledge of the recovery process is also important.

Original planning data, measurement methods, and hydrogeological knowledge of old mines are also indispensable after the abandonment and during the filling up of the mines.

REFERENCES

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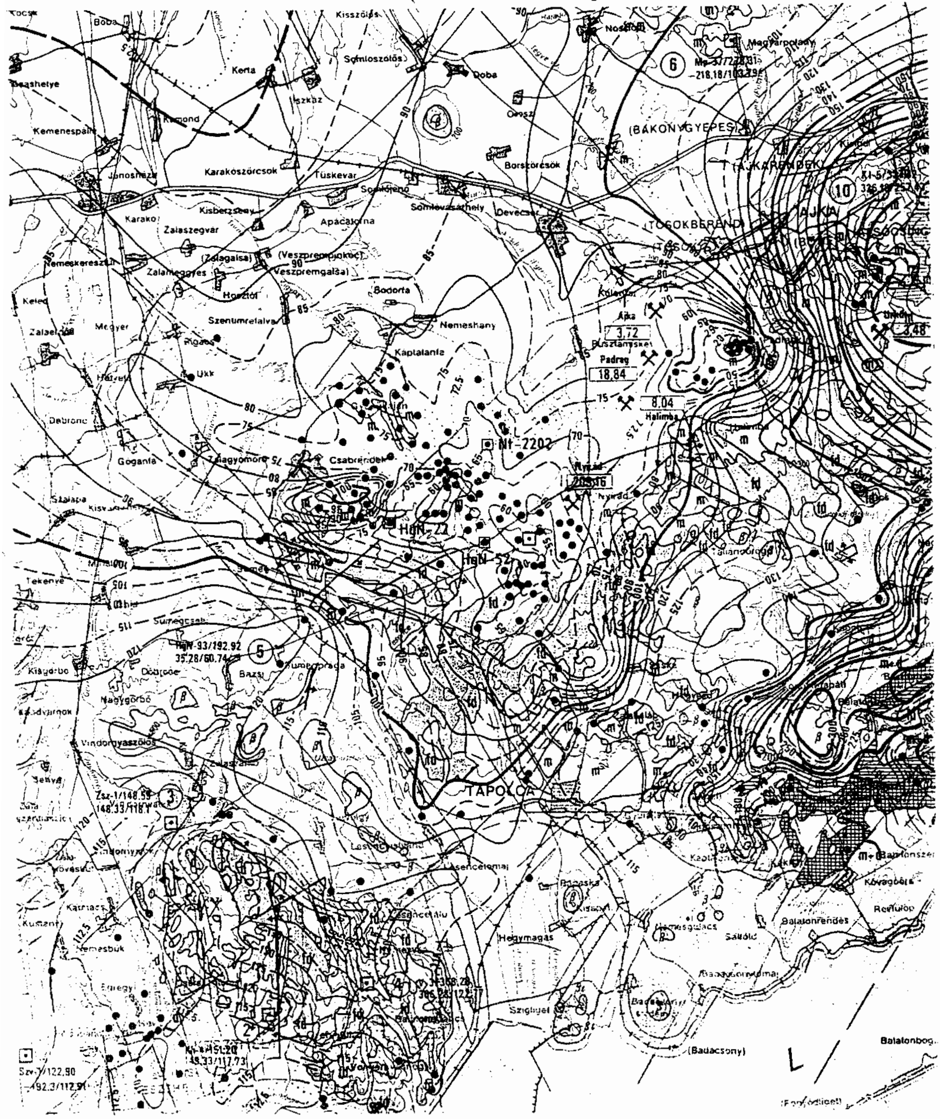
[2] Alföldi, L.: Observation of Pollution Sensitivity of Ground Waters, Journal of the Hungarian Hydrological Society, 1 (1994).

[3] Farkas, I.: Reliability of Transmissibility Tests of Nyirád Research, Ph.D. Thesis, p44 (1987) (In Hungarian).

Figure 1: **Contour map of main karst water surface and piezometric pressure (January 1, 1991) 1:200 000**

Legend:
- Surface karst formation (Miocene)
- Limestone (Eocene)
- Water reservoir (Upper Trias - Bottom Jurassic)
- Water level observation point (See water level change on Fig. 4.)



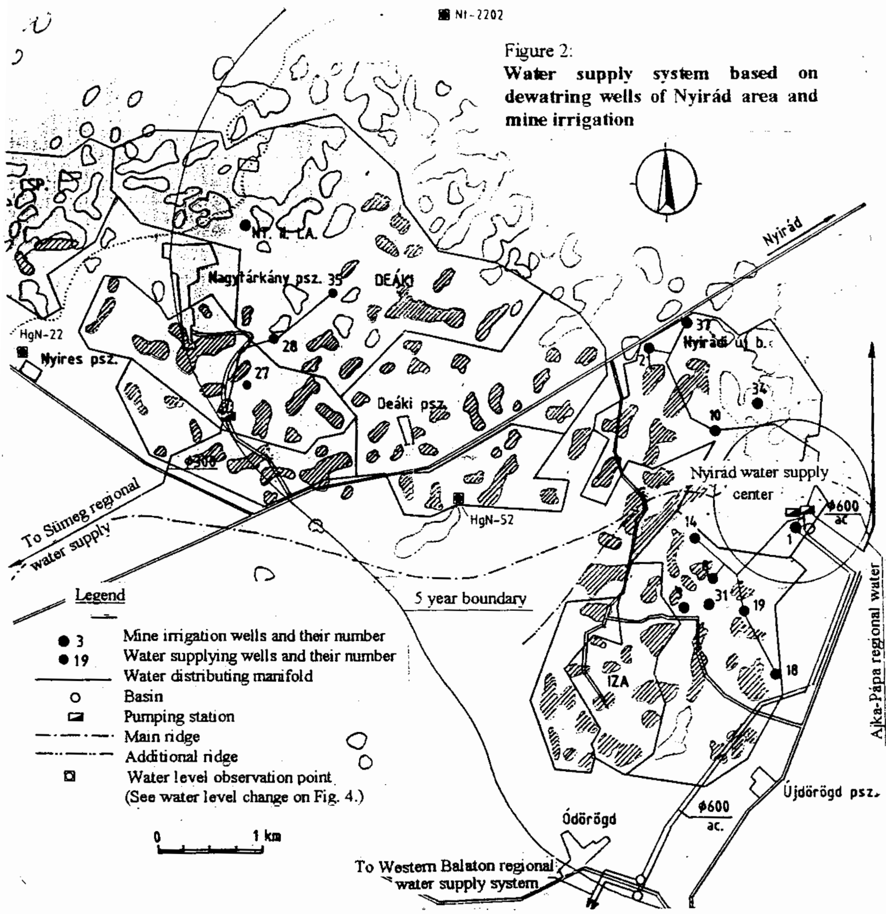


Figure 2:
Water supply system based on dewatring wells of Nyirád area and mine irrigation

Figure 3: **Geological cross section**

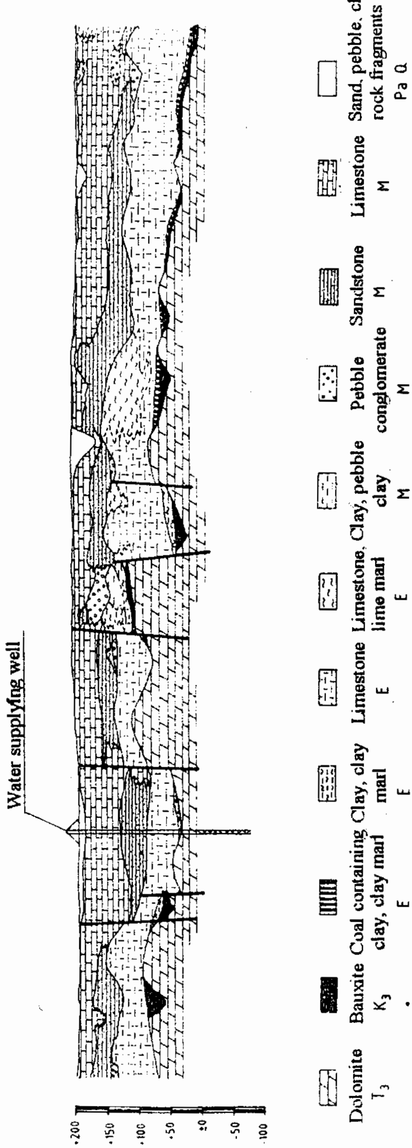


Figure 4: Planned and actual rate of filling up at several characteristic points