Mežica lead and zinc mine closure impact on hydrogeological conditions in upper Meža valley

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Abstract: After the closure of the Mežica mine almost a volume of 1.700.000 m^3 of old mine galleries were flooded and also 360.000 m^3 of flotation mud deposited in those galleries. While the actual flooding dynamics was essentially different from the predicted the quality of mine water flowing from the mine was very well assessed.

Keywords: lead and zinc mine, mine water, regional depression cone, karst-fissured aquifer.

INTRODUCTION

Exploitation of lead and zinc ore in the carbonate layers in Mežica area (Northern Karavanke) has over 300 years of tradition. Ore deposit was developed on the area of 64 km^2, miners were excavated over 1000 km of galleries and about 19 million tons of lead and zinc ore. In 1988 a decision was made to gradually cease the exploitation because of diminishing of ore stocks, increasing exploitation expenses and very high expenses connected with water abstraction. By closing the mine water flooded a greater part of the regional depression cone which was risen from +268 m asl to +416 m asl. On the level +416 m asl mine water flows to the 6 km long water gallery and outflows to the Meža river surface water. To preserve water environment at the adequate state and also to preserve the existing water resources suitable for future use it was necessary to predict the quality of water in the mine after filling up and also the quality of outflowing water to the Meža river. To perform the eventual protection measures also after stopping the abstraction it was necessary to predict the dynamics of depression cone rising and filling up the galleries.

FLOODING DYNAMICS AND MINE WATER OUTFLOW QUALITY PREDICTION

Mežica ore deposit is developed in Triassic carbonate rocks – limestones and dolomites. The area is of rough mountainous relief rising from 500 m asl to over 2000 m asl. The hydraulic barriers of the depression cone are well known to the northern and southern side, where there are outcrops of practically impervious rocks. Boundary conditions to the east and west side could not be well defined, because there is no evident geological barrier. The whole Meža watershed area till Mežica extends over 170 km^2. Effective precipitation rate on this are was estimated to 2.99 m^3/s, while the surface runoff is 2.35 m^3/s[1]. Infiltration rate is thus 0.64 m^3/s (which is 21 % of effective precipitation).

Regarding the effectuated tracer experiments and the extension of karst-fissured unconfined aquifer it was assessed that the area of regional depression cone most probably occupies approximately 83 km^2 and that the equivalent depression radius is 5140 m. It was adopted that the effective porosity of the karst-fissured aquifer system is 1 %. For the volume of depression cone there was adopted a geometry of logarithmic depression cone by the following expression:

$$V = \pi \int_0^h e^{\frac{2(y-b)}{a}} dy \qquad a = \frac{h}{\ln \frac{R}{r}} \qquad b = -\frac{h \ln r}{\ln \frac{R}{r}} \qquad V = \frac{\pi a}{2}\left(e^{\frac{2(h-b)}{a}} - e^{-2\frac{b}{a}} \right)$$

R=regional depression cone radius (m), r=equivalent radius of excavation area on the bottom of the depression cone (m), h=depth of depression cone (drawdown) (m)

Real dynamics of the depression cone rising was essentially faster than predicted. The reason was mainly laid in the estimation of two parameters, i.e. either in the depression cone extension assessment either in adoption of effective porosity value. By actual data of the water table rise the area of real depression cone could be estimated as 83 km^2 area at the effective porosity m_{ef}=0.36 % or as 25,5 km^2 area at the effective porosity m_{ef}=1 %.
On the basis of depression parameters the estimation of the transmissivity was made:

$$T = \frac{Q}{2\pi h} \ln \frac{R}{r} = \frac{Q}{2\pi a}$$

Q=stabilized mine inflow (m^3/s)

Regional hydraulic conductivity (k) derived from the transmissivity estimation would be then $4.5*10^{-6}$ m/s < k < $6*10^{-6}$ m/s adopting the values of regional depression cone radius between 2850 m and 5140 m. The range of the piezometric gradient would be between 7.7 % and 4.1 %.
According to sedimentological and paleontological characteristics, ore bearing limestone and dolomite of Central ore deposits (Union) originated during lagoon sedimentation. The 1000 to 2000 m thick rock succession consists of different varieties of limestone, from stromatolitic and oncolitic beds, varying breccias and dolosparites. There is an alternation of mentioned beds that are each 1 cm to several meters thick[2]. The mineral composition of Mežica ore bodies is very simple. Primary minerals are galena, sphalerite, wurtzite, marcasite, pyrite, dolomite, calcite, fluorite and barite. Secondary or oxide minerals that occurred in oxidation zone are: cerussite, anglesite, wulfenite, hydrozincite, hemimorphite, descloizite, smithsonite, massicot, litharge, greenockite, melanterite, minium, limonite… The lead and zinc ore contains generally very few amounts of trace elements. Sphalerites contain in some higher amount elements of cadmium and germanium[3].
On the basis of the researches made in the years before closing the mine it was predicted that about 10 % (app. 50 l/s) of the total mine outflow (460 l/s –530 l/s) will circulate from the deeper part of the mine after the closure. The prediction of what will be the

water quality of the mine outflow into the Meža river after the flooding was made by laboratory experiments of flotation mud ablution and by measurements of contamination of mine water inflows circulating directly from the aquifer and indirectly through the old mine galleries also partly filled up with flotation mud. Laboratory experiments showed that the effect of ablution of flotation mud could cause mainly the increase of the contents of the following elements: Zn, Fe, Pb, As, Cu and Ag, and in minor portion of NH_4^+, NO_2^-, SiO_2, NO_3^-, F^-, Mg^{2+}, Mn, Ca^{2+}, Na^+, K^+, PAH. Thus the natural background of certain elements was estimated and also the expected maximum values of individual contaminated mine inflows. It was predicted that contents of elements mentioned above would not exceed the average contents in contaminated mine water springs before ceasing the abstraction. It was also predicted that the initial outflows would be of worse quality in the starting phase and would also depend on the hydrological conditions. In continuation the effect of ablution would be lesser and lesser and would be stabilized after few years. Table 1 shows values of contents of main elements observed in uncontaminated water inflows during exploitation (1), observed contents in different contaminated mine inflows during exploitation (2), observed values of contents in different parts of the flooded mine after the closure (3) and observed values of contents in overall outflow from the mine after the closure (4).

Table 1. Contents of elements in the Mežica mine water before and after the closure

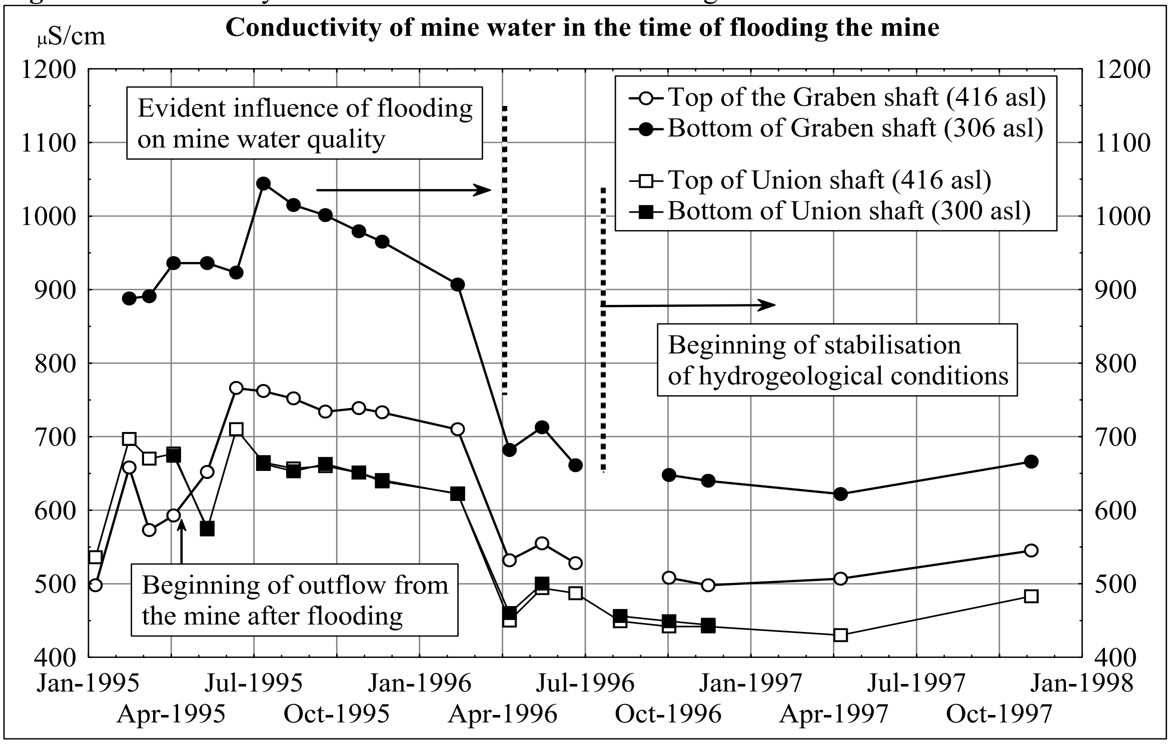
	(1) µg/l	(2) µg/l		(3) µg/l	(4) µg/l
	MAX	MAX	AVERAGE	MAX	MAX
Zn	500	5500	690	3900	680
Pb	33	4500	750	1100	32
Ni				60	28
Cu	6	100	40	141	8
As				14	<5
Cd		150	20	5	1.5
Fe	30	3000	460	880	33
Ag				<5	<5

The contents of individual elements did not exceed the expected values except the Cu content, which was extremely high only in one sample and one event. It was find out that the content of contaminants is significantly proportional to the electric conductivity of mine water. Values of electric conductivity in Figure 1 show clearly the augmentation of contaminants in the time from the beginning of groundwater outflow from the mine and the stabilization process that commenced 16 months after the outflow start.

CONCLUSIONS

Crucial parameters for assessing the dynamics of filling up the regional depression cone are radius of the depression cone and effective porosity (m_{ef}) of the karst-fissured aquifer system. The value of m_{ef} obtained by actual filling up data would be between 0,36% and 1% while the hydraulic conductivity ranges between $4.5*10^{-6}$m/s < k < $6*10^{-6}$m/s.

Figure 1. Conductivity of mine water in the time of flooding the mine



The influence of the mine water circulation through the flooded mine galleries on the chemical composition was clearly expressed the first year after filling up and the beginning of outflow. After this period contents of contaminants in overall outflow and in the bottom of the mine didn't exceed the contents in the inflows from the flotation mud contaminated galleries in the karst-fissured aquifer system before flooding.

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