CONNECTION OF MINE WATER UTILIZATION AND ARTIFICIAL RECHARGE

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SUMMARY

The influence of mine water pumping on the natural water balance, as well as on the subsurface and surface water reserves. By instance of the mine water pumping at Nyirád, the original and present situation in the underground water management will be compared.

The unfavourable situation is possibly to be improved by the partly restoration of the original circumstances, by means of pretreatment, as well as by the infiltration of the elevated water into the water bearing formation. Discussion of the infiltration methods, applicable in this domain and the survey of their advantages. The pretreatment of mine water before infiltration. The possibilities of underground water storage. Artificial recharging of aquifers, layered near to the surface, with mine water. The possibility of artificial recharge the mine water, pumped at Nyirád.

INTRODUCTION

As a consequence of mining activity, usually a big amount of water is pumped together with the production of minerals. The removal of this water quantity means, besides the indisputable adavantages from the point of view of mining, also an intervention into the water balance of the subsurface and surface waters. In consequence of the increased mine water pumping, the flow of springs within the hydrological catchment area of the waterbearing formation decreases, more over in the case of great drawdowns in water level, the outflow comes to an end. However the deficiency after this activity in water quantities, may be supplied by the means of regional water works, based on the mine water pumping. The sometimes warm surplus water, leaving the mine, may be harmful for watercourses and recipiants,from the point of view of environment and water quality,by the growing eutrophycation and by the settling of mineral materials.

The water quantity,pumped in the interest of mining,often exceeds the natural replacement of water and by emptying the subsurface volumes of storage,a significant amount in water reserves is getting lost,which would be a valuable supply and aid for the water management within other circumstances.

The previously mentioned points of view,without the demand for completeness,are well known for the technical public opinion and with the beginning of the large scale mine water pumping activities,also important initiatives happened in the interest of reduction and elimination of the disadvantages.In this study,the author wishes to point at the possible favours in connecting the methods of mine water pumping and those of artificial recharge, as well as those of underground storage,widely used in other fields of water management,on the example of the mine water pumping at Nyirád.

ARTIFICIAL RECHARGE

The artificial recharge is a well known procedure in water management,by which the infiltrated surface water is cleaned and partly stored in the porous aquifers and fissured rocks.The water,induced in this way,is thoroughly mixed with the original water in the aquifer,during the period of seepage.The temperature of the water is also equalized,if the requiered retention time is secured.The induced water is pumped out through wells,respectively galleries,the traditional means of water catchment. On surface,the water is treated,if necessary.This method of water production is used all over the world and by the means of it,the output of the waterworks,utilizing subsurface water,the quality of water in them and the security of production is improved by the water quantity stored underground.Of course,the possibilities to improve the water quality are existing only in aquifers,composed of grained,filter type material.In the carstic,fissured rock,supplying the mine water,the previously mentioned cleaning effect is not existing,however the storage of water,by the aid of underground weirs in these type of rocks is well known long ago.This method of storage was used primarily in the near vicinity of natural springs and artificial catchment structures of wells.In the case of thermal water utilization,the injection of the cooled water back into the original aquifer is also widely practised.If the mine water fulfills the quality demands of drinking water,it can be used directly for drinking water supply purposes and the remaining surplus water,which is normally led to the watercourses,or a part of it may be induced into the fissured rock in the vicinity of springs, to recharge and to restore them,as well as to collect water in the pores and fissures of the rock,without disturbing the mining activity.Of course,the mine water flowing in the watercourses may be used also for traditional artificial purposes too.

Artificial recharge may be applied in the case of covered carstic formations by the use of injection wells,however in open carstic rock by the use of infiltration basins. The water to be recharged artificially,must be pretreated on an open field of filtration before injection.This is not necessary,if the mine water to be recharged,is produced in drinking water quality and it is conducted through a pipe to the location of infiltration,respectively to that of injection.

THE POSSIBILITY OF ARTIFICIAL RECHARGE IN THE NYIRÁD AREA

The utmost widespread triassic dolomite and limestone formations in HUNGARY are to be found in the Hungarian Central Mountain Range.Significant layers of coal and bauxite are included in the former,carstic rocks.The mining of these minerals is only by parallely conducted mine water pumping possible.

Before the mining activities,in the XIX. century and almost till the beginning of the sixties,this area was famous about its plenty of springs,producing supreme quality water in aboundant and equalized flow.Figure 1. shows the average natural levels of carstic water within the territory. The carstic water is regularly supplied by the precipitation,which infiltrates through the open surface areas of the carstic rock.After filling up the fissures in the rock, the water is flowing out from the reservoir in the main carstic formation,again to the surface through the springs. This is the dynamic reserve of the carstic water.Generally the natural water output in average equals the infiltrated rain water quantity.The mine at Nyirád is situated at the south western area of the Bakony Range.This part of the territory is definitely separated from the hydrogeological point of view,from the other carstic areas,laying in the eastern and north eastern parts of the Bakony range,by the geological fault line,passing the town Ajka from the East. Figure 2. is demonstrating this area,after the map of the carstic water levels,published in the year book of Water Resources Management /VIZINT/.

Figure 2. also containes the situation of the open carstic areas,important from the point of view of infiltration.The size of this area is all together 294 km² . Over this territory,the annual rainfall is 630 mm in average,about 25%

of this amount is infiltrating. The dynamic water flow is 126000 m³/d. Within the territory of the Western Bakony and the Keszthely Range, originally two springs of major importance existed, the Malomtó /cave lake/ spring at the town Tapolca and the spring of Tapolcafő near the town Pápa. The distance of these springs is almost 45 km. The original water flow in average of these springs is:

Tapolca	42 300 m³/d
Tapolcafő	51 200 m³/d
Sum total	93 500 m³/d

According to the data of the Institute of Water Resources Management /VIZINT, 1979/, the original carstic water springs discharged round 100 000 m³/d quantity of water from the South Western Bakony area into the Lake Balaton. Based on the former data, the dynamic water quantity and the total flow of the springs corresponds each other.

Mine water pumping at Nyirád began in 1957. At that time, the water level was here 176 m.OD. Simultaneously at Tapolca 122 m.OD. and at Tapolcafő 200 m.OD. levels were observed. Between 1962 and 1973, the amount of pumped water from the main carstic reservoir increased in superb measures. At the beginning of 1978, when the pumped water flow reached 410 000 m³/d, the water level in the mine was at 85 m.OD. Simultaneously the flow of the Malomtó spring at Tapolca was still between 8 000 and 10 000 m³/d, at level 120 m.OD. It is worth mentioning, that this spring ceased its flow recently, in 1981. This circumstance is justifying that geological statement, that the sarmathian water bearing limestone of the spring at Tapolca, has in general a partly separated natural water recharge area and the effect of water level fluctuations in the triassic main dolomite, have only a delayed influence on the flow of the spring. Namely, in this territory, more than 20 years were needed for the pumping at Nyirád, to display the final flow ceasing effect on the spring at Tapolca.

In the relation of the spring at Tapolcafő, the influence of pumping succeeded earlier against the former case, however the distance is much bigger, almost 30 km, comparing with the 14 km distance of Tapolca. The flow of the springs at Tapolcafő disappeared about the middle of the sixties. In 1975, the water level was almost more than 30 m below the surface. The rapid changes in water flow and water levels may be explained by more reasons. One of these is to be marked by the pressurized state of the deep carstic layer between the mine and the springs. This enables the rapid extension of the pressure changes, as well as the more faster exhausting of the poorly recharged stored water from the aquifer. The latter may be expressed as the second reason of exhausting the spring water flow. Figure 3. shows, using the data of VITUKI /Research Centre for Water Resources Development/, the drawdown water levels within the influence area of the Nyiréd depression, at the end of 1977, compared to the original situation, shown on Figure 1. From this, the conditions of natural recharge and supply in the open and covered carstic formations may be seen clearly, as well as the impact of infiltration on the shape and extension of the depression cone.

Based on the data and measurements of the cone of depression, deminstrated on Figures 3. and 4. , the flow of mine water, pumped at the end of the examined period, may be checked. From the data of extension of the assymmetric depression cone and from the original, in general not horizontal water levels, the pumped mine water flow was calculated with the equation and method of Léczfalvy /1969/.

By this method, the circle around the spot of pumping is divided in several sections, with central angles β_1, β_2, etc. in a way, that the change of water level within a section may be uniform. The water flow within each of the sections is calculated separately with the following equation:

$$Q_i = \frac{\pi k \,/\, H + \alpha R \,/^2 \, \beta_i}{\ln \frac{R}{r} \; 360}$$

Where:
- Q_i = the water flow of the section m^3/s;
- k = Coefficient of permeability m/s;
- H = the difference of the original water level and the level of drawdown at the pumping site m ;
- R = radius of drawdown in the section m;
- r = radius of the pumped group of wells m ;
- β_i = central angle of section ;
- α = slope of original water level compared to horizontal .

It's worth mentioning, that the value of R is changing in function of time. In the computation, represented in this article, the empirical values of R, observed in the year 1977, were used.

On Figure 4. the areas of sections, the values of R and β_i are reported. The values of α R were provided by the difference of the original water levels at both ends of the distances R.

For the upper triassic main carstic dolomite rock in the Nyiréd area, the following hidrogeological parameters were taken into consideration:

permeability:	$k =$	$7,5 \times 10^{-4}$ m/s
porosity :	$n =$	0,02 - 0,04
elasticity : /rock and water/	$\varepsilon =$	$1,96 \times 10^{-5}$.

Figure 5. shows the scematic longitudinal section of the Nyirád system in the line of Tapolcafő - Nyirád -Tapolca. The covered and open sections of the carstic rock are also indicated in the figure, as well as the water quantities infiltrated at the open areas and the original average water flows of the springs, together with the calculated pumped mine water flow at Nyirád.

The water flows of the different sectional areas of drawdown are, as follows:

$$Q_1 = 0,516 \ m^3/s$$
$$Q_2 = 1,605 \ m^3/s$$
$$Q_3 = 1,355 \ m^3/s$$
$$Q_4 = 0,879 \ m^3/s$$
$$Q = 4,355 \ m^3/s = 376\ 272 \ m^3/d.$$

The summarized, computed flow equals within an accuracy of 10 %, with the average pumped mine water flow of 410 000 m³/d, in 1977.

As a result of mine water pumping at Nyirád, after supplying the drinking and industrial water demands in 100 000 m³/d quantity, 150 000 m³/d water of excellent quality is conducted through the watercourses into Lake Balaton, while a further quantity of 160 000 m³/d is discharged to the catchment area of the river Rába in the North. It can be proved, that for the time being, big amounts of mine water are flowing useless into the recipients. However for the future extended use of the elevated high quality water, there are undoubtedly wide perspectives within the central part of Transdanubia.

As it was mentioned earlier, for the use of mine water in artificial recharge in this area, two possibilities are existing:

a/ Artificial recharge of the aquifers and rocks, bearing carstic water.

b/ Artificial recharge of the sedimental aquifers, laying near to the surface, in the near vicinity of the surface watercourses, conducting much quantities of mine water. /Traditional artificial recharge/.

In the Nyirád area, the introduction of both methods is possible. The possibilities of artificial recharge in the carstic formation will be discussed here.

The introduction of the pumped mine water into the original water bearing strata must be solved in a manner, that the infiltrated water should not cause significant rise of water levels in the surroundings of the mine. For this reason the areas of artificial recharge, should be chosen at those places, where previously, a relatively slow sinking of the water surface, due to the pumping was observed, as well as where the natural infiltration zones are near, however the connection with the main carstic strata is limited. For this purpose, the fissured rocks, forming the underground reservoir of water in the vicinity of the springs, those water ceased flowing, are usually favourable. It may be mentioned, that such places are usually equipped with the structures and installations of the one-times water supply system. The spot of water induction must be chosen so, that the mine water may be conducted there, possibly through gravity pipes. In the vicinity of one - times thermal springs, inasmuch the pumped mine water is also warm, the injection of water is advantageous through wells in the deep reaches of the formation, taking the hydrogeological conditions of the catchment area also into consideration. In this way, a chance is also given to preserve the heat content of the pumped mine water too.

It is clear, from the previously mentioned aspects, that within the influence area of mine water pumping, only limited possibilities for the method of artificial recharge are existing. Out of this area, however the method has favourable chances of use. In the Nyirád area, the vicinity of the Tapolca Malomtó spring, seems to be in favour for introducing this method. About the passed flow of the spring mention was done previously. The cave with an underground lake, as it is well known, is situated in the 100 - 200 m thick sarmathian limestone, which is layered on the upper triassic main, carstic dolomite strata. The the limestone has its own, from the main carstic layer partly isolated, underground storage system, which, on the base of experiencies, delayed the dewatering of the rock and contributed significantly to the longer existence of the spring. The place of water induction may be chosen, after the evaluation of several variants, about 1 - 1,5 km distance, northward from the cave lake, near to water - course Viszló, which is conducting the mine water of Nyirád to Lake Balaton. The infiltration may be accomplished by a row of infiltration wells, which are recharged either with the water, taken directly from a gravity pipe, or with the water, taken from the creek. In the latter case, the water must be treated previously with a surface, collector **drain** filter field, situated near the injection wells. The induction of water is calculated in an informatory way, using the equation of the free surface injection well, as follows:

$$Q_b = \frac{\pi k \,/2\, H\, s + s^2/}{\ln \frac{R}{r}}$$

where:

Q_b = injected water flow; in this case, the original 0,49 m³/s flow of the spring,

H = 120 m, the depth of water in the domain near the spring,

s = the pressure head of the recharged water in m,

R = 1 000 m, distance between the injection wells and the spring,

r = 100 m, average radius of the injection well group,

k = permeability $7{,}5 \times 10^{-4}$ m/s.

Using the former values, the pressure head "s" may be calculated, in this case its value is s = 1,7 m. The flow of circle section 1., shown on Figure 4. is computed with the modification in water level the value of "s", is

$$Q_1 = 0{,}568 \text{ m}^3/\text{s}.$$

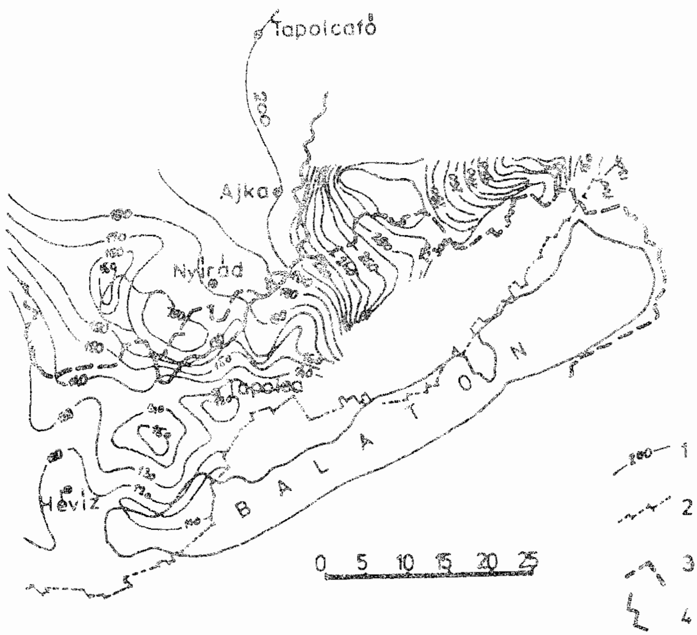
This flow is greater than the originally computed flow of 0,516 m³/s. The difference is 0,053 m³/s, almost 10 % rise in the mine water pumping. Simultaneously the flow of the spring at Tapolca will be

$$Qf = 0{,}437 \text{ m}^3/\text{s}$$

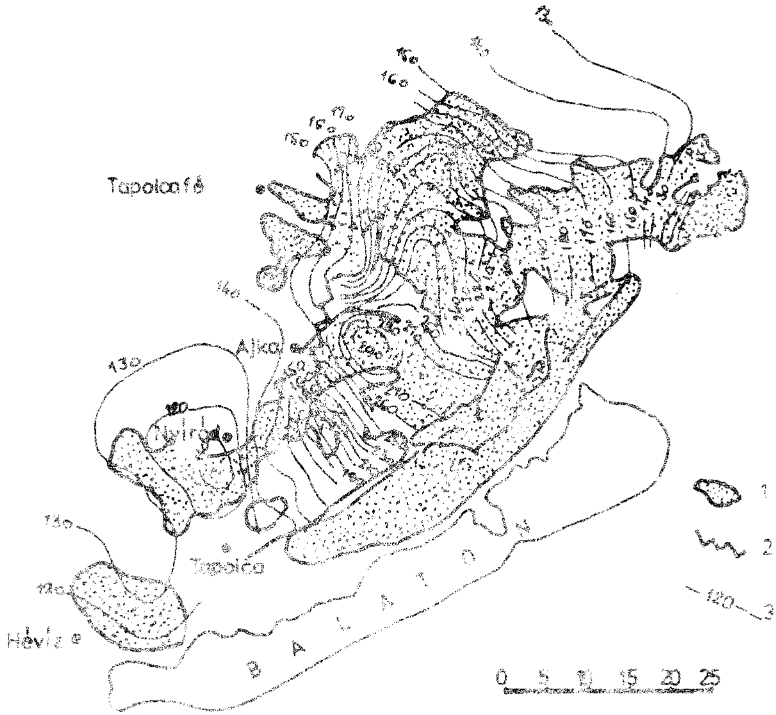
From the former calculation, the limitation in artificial recharge, in areas of great drawdowns in the water level, is clearly to be seen. Of course the induced water is filling up the separate reservoir of the spring and in this way certain local water reserves are also developed.

On the base of the suggestion, discussed here, the analysis of the possibilities in artificial recharge, within the whole area would be advisable in the frames of a comprehensive detailed study, stressing the importance on the restoration of the springs in Tapolca and Tapolcafő and to avoid the depletion of flow at the Lake of Hévíz.

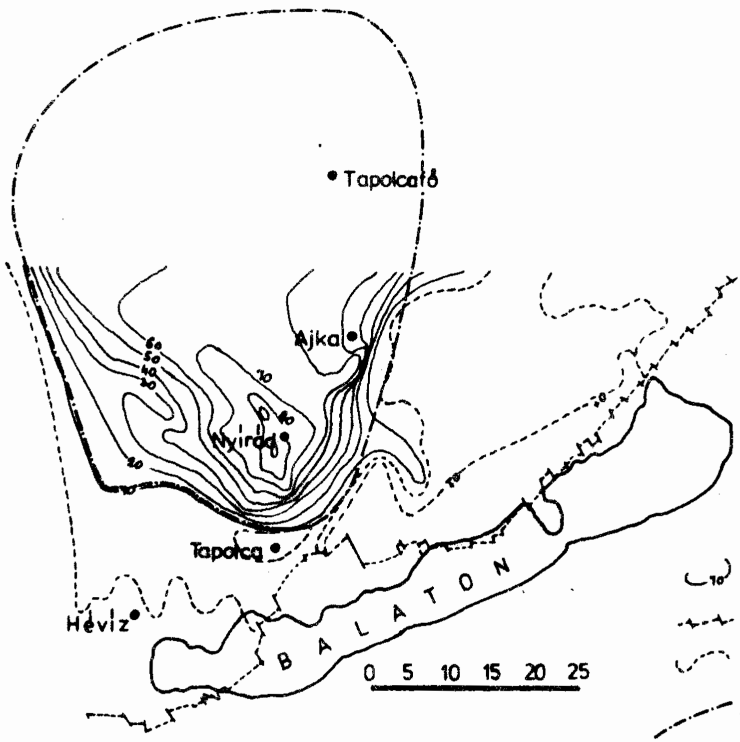
LIST OF FIGURES


Tapolcafő
Ajka
Nyirád
Tapolca
Hévíz
B A L A T O N
0 5 10 15 20 25
1
2
3
4

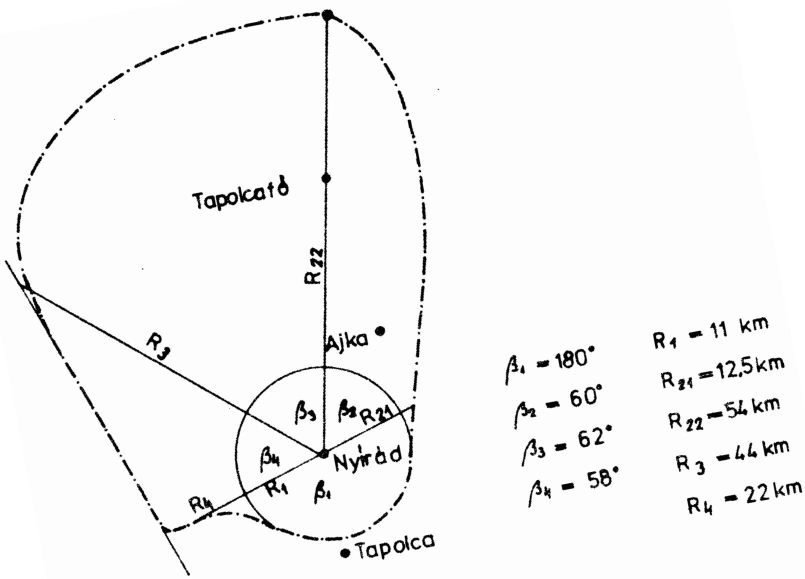
1.ábra Fig.1


Tapolcafő
Ajka
Nyirád
Tapolca
Hévíz
B A L A T O N
1
2
120
3
0 5 10 15 20 25

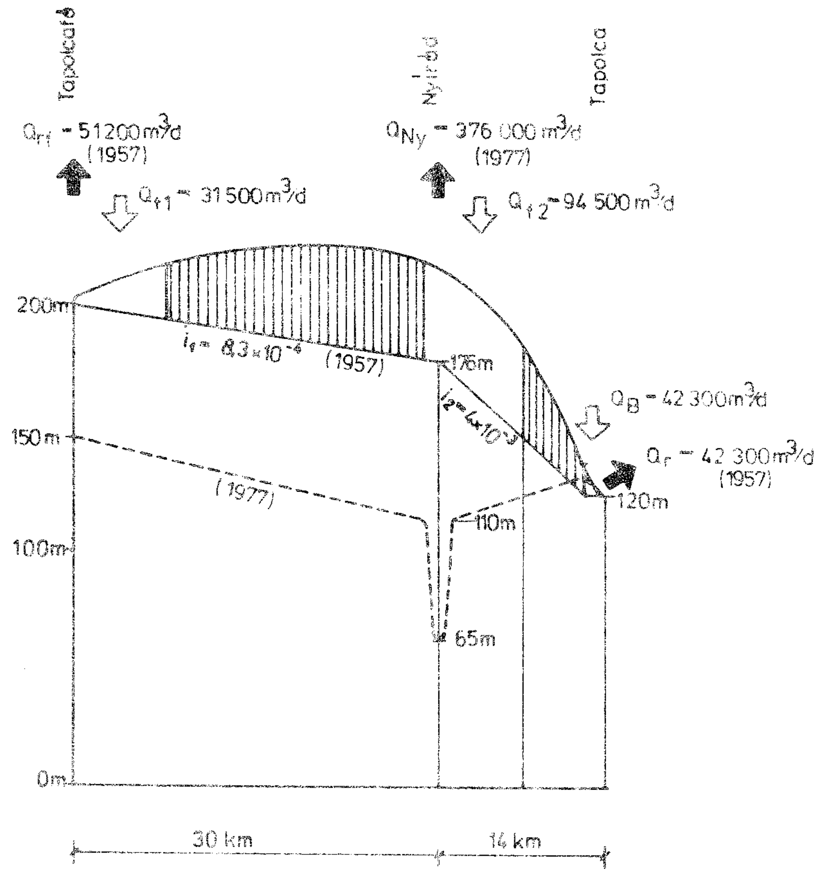
2. ábra Fig. 2


Tapolcafő
Ajka
Nyirád
Tapolca
Hévíz
BALATON
0 5 10 15 20 25
1
2
3
4

3. ábra Fig.3


Tapolcafő
R22
Ajka
R3
β3
β2
R21
β4
Nyírád
R4
R1
β1
Tapolca
β1 = 180°
β2 = 60°
β3 = 62°
β4 = 58°
R1 = 11 km
R21 = 12,5 km
R22 = 54 km
R3 = 44 km
R4 = 22 km

4. ábra Fig. 4


Tapolcafő
Nyirád
Tapolca
Q_{rf} = 51200 m³/d
(1957)
Q_{Ny} = 376 000 m³/d
(1977)
Q_{f1} = 31 500 m³/d
Q_{f2} = 94 500 m³/d
200m
176m
i_1 = 8,3 × 10⁻⁴
(1957)
Q_B = 42 300 m³/d
150 m
Q_r = 42 300 m³/d
(1957)
(1977)
120m
110m
100m
65m
0m
30 km
14 km

5. ábra Fig. 5