Post-closure Water Management Practice on the Former Uranium Mining Site in Hungary

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Abstract
During the mining of uranium ore (1958-97) app. 72 million m^3 mine water was removed part of which was utilised in the mill partly treated prior to discharge it. After the termination of the uranium ore mining two water treatment stations were built and the water management practise was reorganised into an integrated water management system.
Challenges in respect of water management among others are connected with answering the questions: how long the mine water treatment has to be continued and how the efficiency of the groundwater restoration in the vicinity of the tailings piles can be enhanced?

Key words: water management, mine water treatment, groundwater restoration.

Introduction
The main sources of the contaminated waters are the former mines, waste rock piles (WP), tailings piles. Waters originated from these objects are contaminated either with uranium (mine water, seepage from waste rock piles) or with high concentration of total dissolved solids (TDS). The post-closure water management is directed mainly on the restoration and protection of the groundwater as well as the protection of the surface water quality. For this:

- Hydrological depression funnel is maintained in the shaft N1 by pumping the uranium-contaminated mine water from the mine;
- The uranium-contaminated seepage from waste rock piles is collected and treated;
- The highly contaminated (Mg, SO4, Cl) groundwater is extracted in the vicinity of tailings piles;
- All waters (treated and untreated) are collected in a common discharge basin (discharge point) for controlled and monitored release of the water from the site.

The treatment of the polluted waters is carried out in the central water treatment installations or on the site if local treatment is favourable (e.g. low volume of water). For possible passive groundwater treatment an experimental permeable reactive barrier is under investigation (Csővári M. et al. 2005).
As a part of the overall remediation the most important investment relating to the water management were:

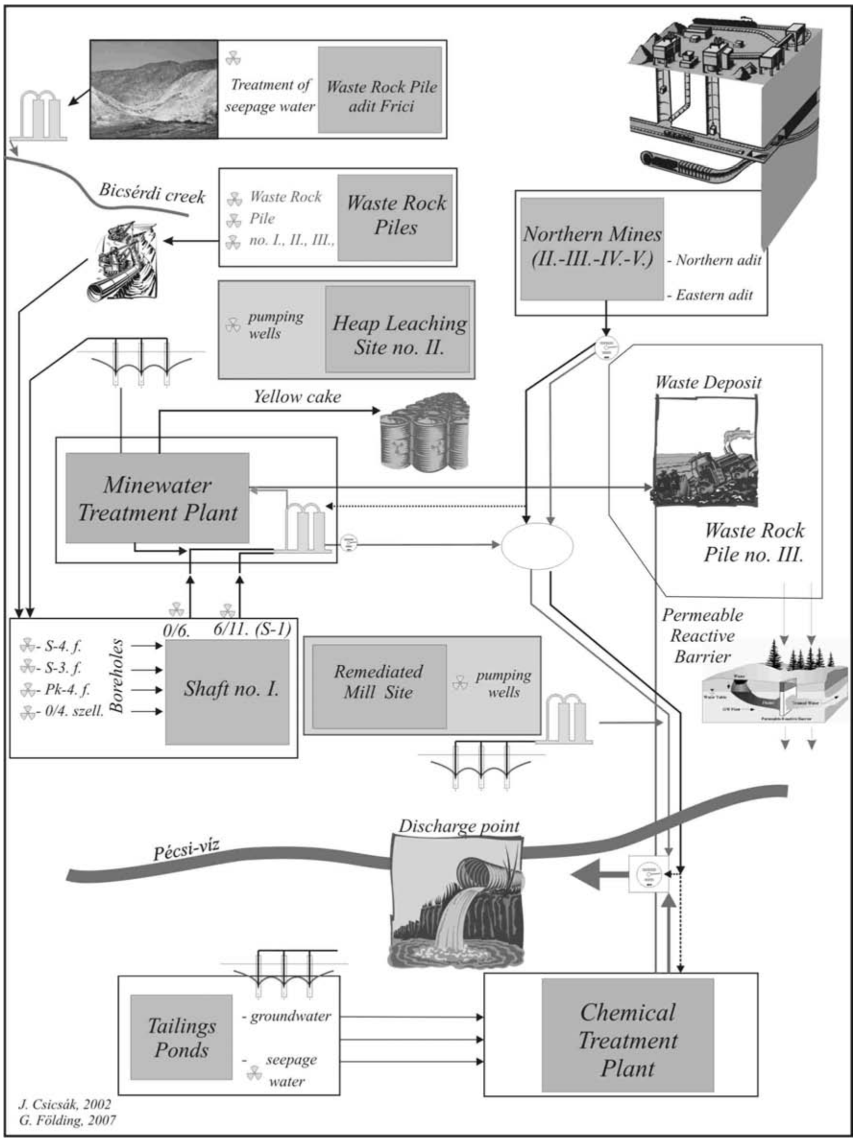
- Constructing new **mine water treatment** station for treatment of uranium-contaminated waters,
- Building a ***pump and treat*** station for groundwater quality restoration around the tailings piles,
- **Construction of 5.6 km long pipe line** for directing the seepage from waste rock pile N2 to the mine water treatment station;
- Compiling a general **integrated water management** system.

For the local groundwater restoration site-specific methods and installations were planned. The water treatment and water management practise is described in the following.

Integrated water management system
The simplified flow chart of the developed water management system is presented in the figure 1.
Main part of the system is the two central water treatment stations in which uranium-contaminated waters (mine water, waste rock piles' seepage) and the magnesium-contaminated groundwater is

treated. In some cases - if the volume of water is small or it is extremely difficult to direct it to the water treatment station - the contaminated water is treated *on-site*. The treated water is discharged into the receiver *Pécs-víz* through the sole discharge point, and a very small part of it's in the *Bicsérdi creek*. The water treatment processes are described in the following sections.

Figure 1 *Simplified chart of the integrated water management system*



The content of the flow chart can be summarised as follows.

Seepage from one small waste rock pile (*Frici WP*) is treated *on-site* while that of from *WP1,2,3* on the mine water treatment station; these later waters are collected through absorbing wells in the shaft cavities. Seepage from *WP2* is directed to the station through 5.6 km long pipeline. *On-site* treatment would be difficult because of the site specialty. Contaminated groundwater found during the cleanup activity on heap leaching site N2 is extracted by wells is directed into the mine and after all is treated in the nearby mine water treatment station. The deep northern mines are still under flooding; for the time being the water coming from two adits (Northern and Eastern adit) is not treated because of the low contamination. This water together with the real mine water is treated on the mine water treatment station. The recovered uranium is obtained in form of yellow cake which is a commercial product.

Experimental permeable reactive barrier is constructed (EU-project) for the investigation of the in situ treatment of uranium-contaminated groundwater. During post-closure monitoring some groundwater

contamination was found on the former mill site, where the contaminated water is being removed and treated *on-site* on ion-exchange columns.
The contaminated groundwater removed on tailings piles site is treated in the chemical water treatment plant, the sludge from treatment is deposited in the separate repository area on WP3 (*Waste deposit*) together with other uranium-contaminated wastes from mine water treatment station. All collected waters - both treated and untreated - are discharged through the sole discharge point, where the water parameters are controlled continuously (specific conductance, pH, volume) or by grab sampling (U, Ra, TDS). The specific conductivity of the water in the **receiver** is also measured both upstream and downstream. The maximum discharged volume of the water is calculated on the bases of these data taking into account the restriction: the specific conductivity of the water in receiver must be kept bellow 2000µS/cm. In following sections the treatment processes used are briefly discussed.

Treatment of uranium-contaminated waters
Presently uranium is removed only from the mine water of the shaft N1 and from seepages of waste rock piles using anion exchange process and precipitation of the removed uranium from the elute with hydrogen peroxide. The details of the used process can be found in some publications (Csicsák et al. 2002, Csővári at al 2005). The mine water treatment station is capable for treating 1.2 million m^3/year of mine water.
If during the cleanup activity uranium contamination is found on some particular areas the removed water is treated *on-site* on ion exchange columns (e.g. mill site).

Challenges
The uranium concentration just after the termination of the shaft N1 in 1968 was on the level of 6-7 mg/l; nowadays it is 4.5 mg/l. This means that the attenuation of the uranium concentration in the mine water is a very slow. The challenge is to facilitate this process. It is supposed that the slow decreasing of the uranium content is due to the huge three-phase rock volume (containing uranium minerals) above the saturated zone from where the mine water is pumped (106 m depth). This water level is maintained by pumping for creation a depression funnel prescribed earlier by the authority aiming at protection of the nearby drinking water aquifer. Now it is supposed that some elevation of the water level in the shaft could result in decreasing the uranium concentration in mine water in long term by decreasing the reactive zone. At the same time in short term some increasing of the removable uranium is expected as a result of washing through some part of the presently not flooded cavities. For checking of this idea a full-scale experiment is planned during which the water level in the mine will be increased (up to 80 m). The result of this experiment perhaps will be essential for long term planning of mine water treatment.
The **other challenge** is the determination of the composition of the expected deep mines' water which are presently under flooding (present water level is on the depth of 600 m) for answering the question whether this water has to be treated or not if enters the surface? Sampling is planned in 2008.

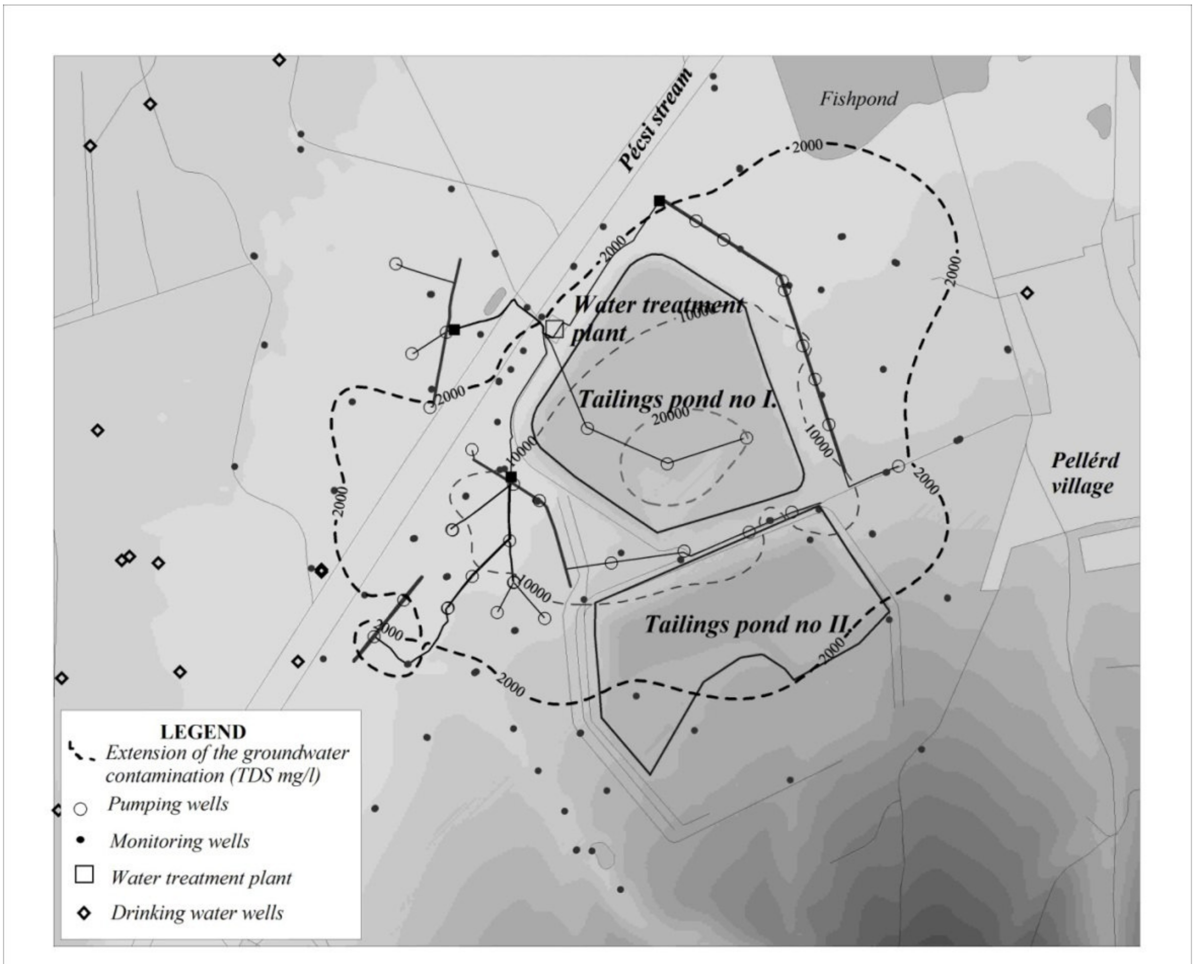
Groundwater restoration practise
Because of the lack of appropriate isolation of the bottom of the tailings ponds app. 20-23 million m^3 highly contaminated tailings water (~22 g/l TDS) leaked into the subsoil from the tailings piles. As a result the groundwater is highly contaminated first of all with magnesium sulphate and sodium chloride. For the restoration of groundwater quality pump and treat system consisting of water extracting wells (27 wells), drain at 6-9 m depth (3.25 km long) and water treatment station were built. The water is extracted from two levels: the shallow groundwater is more contaminated (10-15 g/l) than the deeper one (4-6g/l). For treatment lime milk is used. The TDS of the treated water drops from the average 12 g/l to app. to 6 g/l (magnesium and sulphate is precipitated). The isolines of the contamination plume around the talings piles (shallow groundwater) and the position of the groundwater extracting system are illustrated in the figure 2. The groundwater restoration system has been operating since 2001. During this period app. 3.7 million m^3 of contaminated groundwater has been extracted with average TDS of 11 g/l. The slow attenuation of the contamination is due to the high volume of the contaminated pore water in the tailings (app. 6 million m^3), which still seeps into the subsoil. To accelerate the restoration process recently three extracting wells were deployed just on the tailings pile but sunk into the subsoil. The finishing of the covering of the tailings piles (which is

planned for 2008) most likely will result in substantial decreasing of the seepage rate from the tailings and a faster attenuation of the contamination of groundwater will take place. Nevertheless it seems that the groundwater restoration process has to be continued yet.

Conclusions

Practically all contaminated waters are collected and treated if needed and discharged through sole discharge point where the parameters of the discharged water are measured or controlled. Both mine water and groundwater treatments have to be continued because the concentration of the contaminants is still high both in the mine water and the groundwater.

Figure 2 *Contamination of the pore water in and under the tailings*



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