Remediation of consequences of chemical leaching of uranium in Stráž pod Ralskem

Jiří Mužák

DIAMO, s. p., o. z. TÚU, Dept. of mathematical modelling, Máchova 201, 471 27 Stráž pod Ralskem, e-mail: muzak@diamo.cz, tel.: +420 487 894 324

Abstract

This paper presents information about a complex project of remediation of the consequences of in-situ chemical leaching of uranium in Stráž pod Ralskem, conducted by DIAMO, s. p., o. z. TÚU. A total of more than 4 million tons of sulfuric acid and other chemicals has been injected into the ground during the period of chemical leaching of uranium. These have contaminated more than 300 million m^3 of ground water. For remediation, an active pump and treat remediation approach is now used and an innovative passive in-situ immobilization approach is planned.

Key words: uranium mining, ground water, contamination, remediation, Czech Republic

History of uranium mining

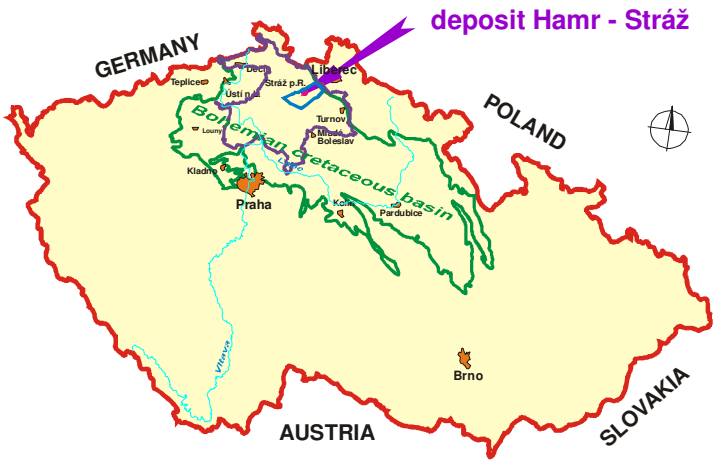
The history of uranium exploitation in the Czech Republic (and in the former Czechoslovakia) dates back 60 years. Over the initial period, from 1946 until the beginning of the 1950s, exploitation was mainly carried out in the reopened mines of the Jáchymov mining area. Rapid development of surveying and extraction work was reflected in the large growth of exploitation in other areas of Bohemia and Moravia. This work affected the regions Příbram, Hamr-Stráž pod Ralskem and Dolní Rožínka, i.e. southern and western Bohemia. More than 100 000 tons of uranium have been extracted from more than 800 trial and production shafts since 1946.

Because of the diversity of the deposits, uranium exploitation was carried out with the whole spectrum of mining methods available, which were selected as appropriate for the host rock at the given locality. In general terms, there are two basic methods of uranium extraction applied in the Czech Republic:

- conventional underground mine workings, and
- underground leaching in situ.

The deposits in the area of Hamr - Stráž were discovered in the 1960s. In 1963, aerial geophysical surveying detected high magnetic anomalies into which a borehole, HJ-1 (Hamr na Jezeře-1) was drilled. Following the detection of the anomaly at well HJ-1, other exploration boreholes were drilled in its vicinity and all of them confirmed uranium mineralization. Well HJ-1, located in the Hamr deposit, was the beginning of an exploration borehole network. The location of uranium deposits in the area of Hamr - Stráž within the Czech Republic is shown on Figure 1.

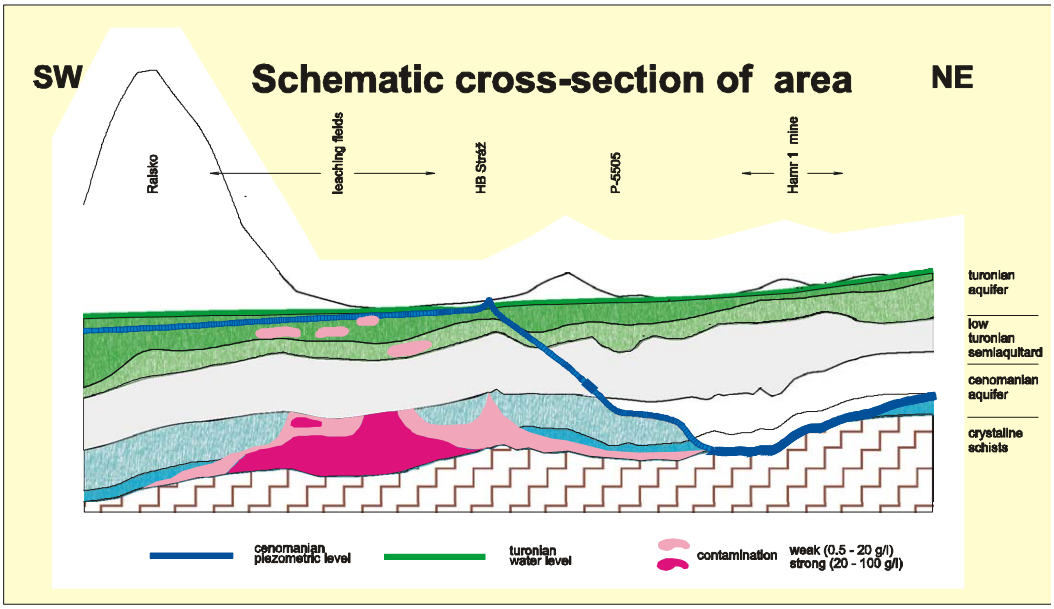
Figure 1 *Location of uranium deposits in the area of Ham*r *- Stráž within the Czech Republic.*



Chemical leaching of uranium in the region of Hamr - Stráž has been conducted since 1967. During this period, there have been many changes in the application of this method, that have brought about an enormous development of leaching fields and boosted uranium production.
Unfortunately this method resulted in detrimental impacts to the environment, especially to the groundwater of the Cenomanian aquifer. As a consequence, water of the Turonian aquifer in close proximity to high-quality potable water sources was also jeopardized. For this reason it has been decided to decommission and remediate the chemical plant.

Ground water contamination
Overlying the deposit there are two aquifers: the Cenomanian and the Turonian, separated by the low Turonian aquitard. A schematic cross-section of the mining/remediation area is shown in Figure 2.

Figure 2 *Schematic cross-section of mining/remediation area*



Over the period of chemical leaching of uranium (ca. 32 years), more than 4 million tons of sulphuric acid and other chemicals have been injected into the ground. Most of the products (approx. 99,5 %) of the reactions of the acids with the rocks are located in the Cenomanian aquifer, the contamination of which covers an area larger then 24 km^2 and affects a volume of groundwater greater than 300 million m^3. The total amount of dissolved SO_4^{2-} is about 3,6 million tons (4,9 million tons of total dissolved solids). Approximately 0,5 % of the contamination is located in the Turonian aquifer, and takes the form of locally isolated plumes. The total amount of dissolved SO_4^{2-} is about 11 500 tons (15 500 tons of total dissolved solids), and the volume of groundwater affected is 35 000 m^3.
Both aquifers are contaminated mainly by SO_4^{2-}, NH_4^+ and Al. There is no natural 'self-remediation' of the contaminated groundwater.

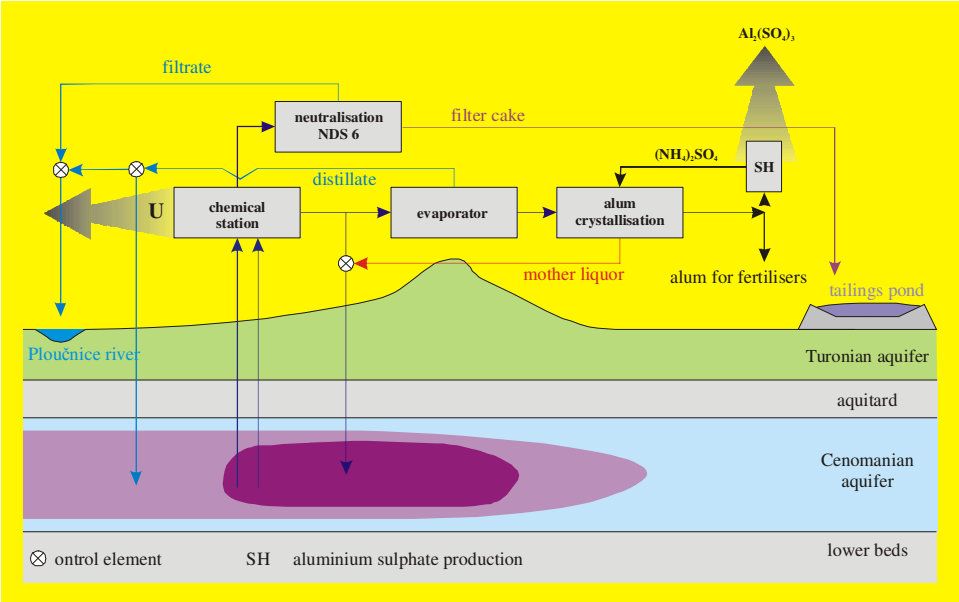
Remediation
Remediation of the consequences of chemical leaching of uranium in Stráž pod Ralskem is a complex problem, consisting of a variety of partial solutions. The Czech government adopted two separate resolutions with respect to this matter, namely the Governmental Decree of 20th May 1992 No. 366, determining a transitory period between 1992 – 1994 that involved a special regime of exploitation, and the Governmental Decree of 6th March 1996 No. 170 that presented the decision on terminating chemical leaching of uranium in Stráž pod Ralskem.
Assessment of the situation led the Czech government to decide to terminate chemical leaching as of 1st April 1996 and to perform active remediation work.

The objectives of the remedial activities are:

- to restore the rock environment to a condition guaranteeing continuing usability of Turonian water of the Northern Bohemia Cretaceous,
- to decommission bore holes and surface installations,
- to incorporate the surfaces of leaching fields into the ecosystem, taking into account regional systems of ecological stability and urban plans.

For remediation, an active pump and treat remediation approach is being used and an innovative passive in-situ immobilization approach is planned. The pump and treat approach is as follows. Dissolved uranium is separated out at a chemical station from the solution abstracted from the Cenomanian aquifer. After uranium sorption, part of the solution is led to an evaporation station where it is concentrated. Alum is produced from the concentrate during a crystallization process, then reprocessed into aluminum sulfate and ammonium sulfate which are returned back into the crystallization process. The distillate from evaporation is discharged into the Ploučnice River. The "mother liquor" after crystallization of alum is injected back to the ground. Another part of the solution after uranium sorption is decontaminated at neutralization station NDS 6, which decontaminates not only Cenomanian solutions but also a part of the Turonian water and water from internal drainage of the tailings pond. The filter cake from the neutralization process is deposited in the tailings pond. The scheme of these existing surface technologies is shown in Figure 3.

Figure 3 *Scheme of present configuration of surface remediation technologies*



The present configuration of surface technologies does not satisfy the demands of the whole remediation process. Therefore, it is necessary to complete the chain of surface technologies, as shown on Figure 4.

At the beginning of 2010, liquidation of the mother liquor by a neutralization process will start. Stage II of drilling of remediation wells will be finished at the end of the same year. Stage II of aluminum sulfate production will begin operation in 2011. Another neutralization station, NDS 10, will start operation in 2013.

Realization of the planned technologies will cost about 1,9 mld (1.9 US billion) Kč (69 mil. EUR).

The principle of the passive innovative in-situ immobilization approach is to develop special conditions in the water-bearing sandstones under which contaminants can transform from mobile to immobile form. In the case of remediation after chemical mining of uranium on the Stráž deposit, it means injecting a suitable alkaline medium that will spread in the contaminated sandstone aquifer, decrease the acidity of the contaminated groundwater, and cause precipitation of contaminants (SO_4^{2-}, Al, Fe) in pores. This process is followed by co-precipitation and sorption of other toxic contaminants such as As and Be. It thus seems optimal to take advantage of the basicity of the solutions after

neutralization and to inject them into the ground to neutralize less acidic ground water (see scheme in Figure 5).
The pilot experiment of in-situ immobilization is planned for realization in 2008. The results of the experiment will be used to design the application of this method within the remediation process with the aim of decreasing time and costs.

Figure 4 *Scheme of complete configuration of surface remediation technologies*

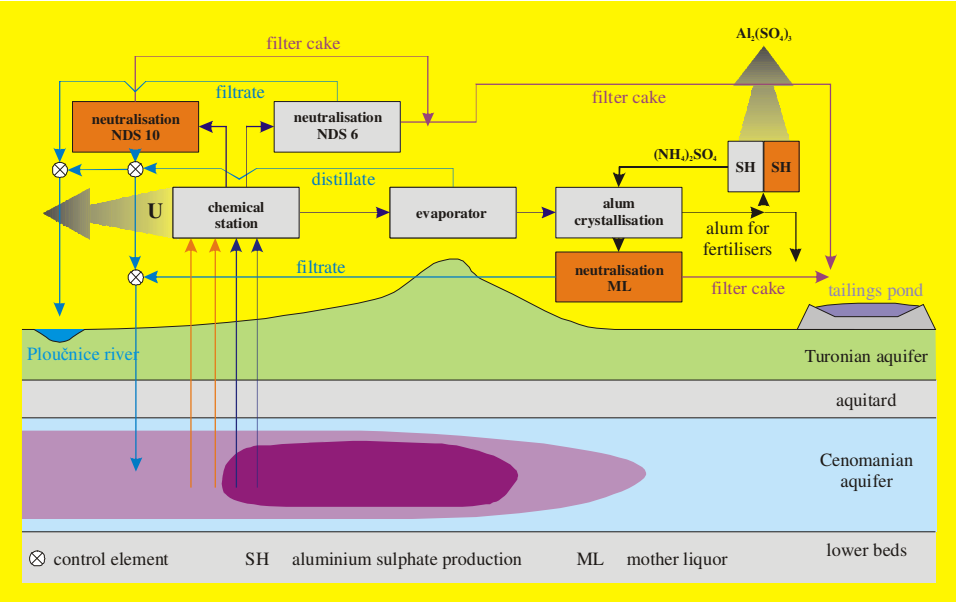
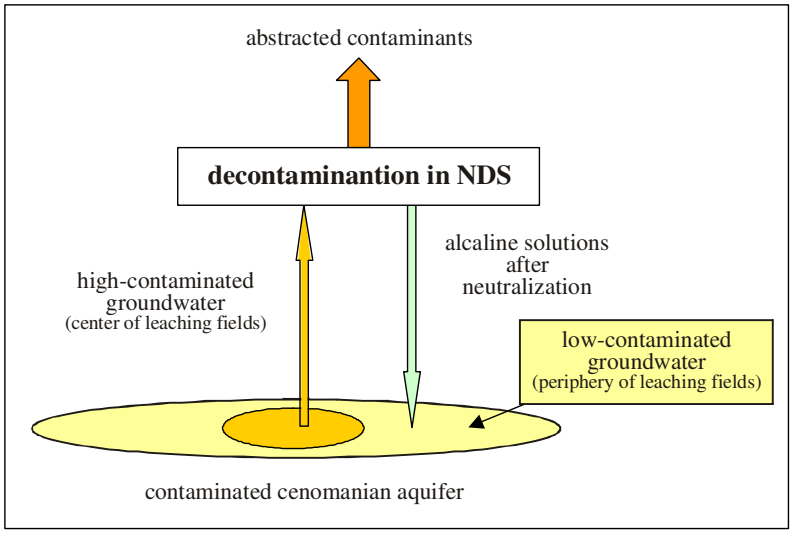


Figure 5 *Scheme of injection of alkaline solutions after neutralization (decontamination)*



Conclusion

All remediation processes are expected to finish in 2035. During this period 3,7 million tons of contaminants (2,8 M tons SO_4^{2-}) will be withdrawn from the ground. The total costs for remediation process are expected to be on the order 40,9 mld. Kč (1,35 mld. EUR).
Decommissioning of chemical leaching of uranium is a long lasting and complex process that must be continuously evaluated and specified. Extensive monitoring, verification and modelling will be carried out until the end of the remediation process, and relevant Czech authorities will continuously approve the process of remediation and its individual components.