ECOLOGICAL CONSEQUENCES OF URANIUM MINING IN NORTHERN BOHEMIA

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ABSTRACT

On the territory of Northern Bohemia, the uranium ore is excavated at the mine Hamr, while at the ore deposit Stráž, the metal is obtained by subsurface chemical leaching by means of boreholes from the surface. Both methods eliminate each other within the uniform hydrogeological structure - Stráž block. Incompetent evalution of hydraulic extraction conditions manifested itself, by leakage of acid solutions into mine waters on the mine Hamr and the broad surroundings of the ore deposit Stráž. Spreading of contamination has been supported by ineffective protection measures. The uranium has been extracted within the Stráž block with considerable storages of a good quality groundwater for supply purposes. This structure forms a part of the protected area of the natural water accumulation (PANWA)- decreed in 1981. The groundwater accumulation, concentrated in Middle Turonian sandstones has been also contaminated by acid solutions over the great part of the ore deposit Stráž. At present, the volume of contaminated water within Cenomanian aquifer attains 188 mil. cb.m. on the area 28 sq.km and in Turonian aquifer 75 mil.cb.m. on the area 6sq.km. The menace of contamination to the drinking water sources in sandstones is actual for all the time. Negative impacts on a landscape ecology are undoubted and induce the necessity of liquidation of the extraction by leaching. This process will be time-consuming.

INTRODUCTION

The mining of the uranium ore is concentrated on the territory of Northern Bohemia, into two neighbouring extraction areas: Hamr and Stráž (Fig. 1,2). The uranium is excavated from basal Cenomanian sediments, at the mine Hamr, by the mining technology (panel and fill method), while at the ore deposit Stráž it is obtained by subsurface chemical leaching by means of boreholes from the surface (ISL-in situ leaching). While the traditional mining reguires a permanent operational drawdown of the groundwater level, the extraction from the surface depends on the high piezometric groundwater head for the formation of suffiecient overpressure. From the hydrogeological viewpoint, both methods eliminate mutually each other. From the first the uranium extraction has been jointed with the changes of piezometric heads, the groundwater flow and the groundwater quality. The ISL has been manifested by the groundwater extensive contamination with acid solutions out of the ore deposit margin, vertically and horizontally. This negative state was supported by inadequate evaluation these factors: position of the extracted ore deposits within the uniform hydrogeological structure - Stráž block, type of leaching solution and conditions for its recharging, uranium bond and time of leaching from layers. A liquidation of the extraction was not solved in advance.

Ore deposit Stráž

The ore deposit Stráž is located at the NW margin of the Stráž block (Stráž structural area). This block is limited by the Stráž fault zone (1 km broad) in the NW, against the deeply sunken (80-100 m) to NW Cretaceous sediments of Tlustec block and by the Lusitanian fault in the NE (Fig. 1,3). The bedrock of the Stráž block creates the aquiclude for mostly sandy collectors of the Upper Cretacesous age. The Cenomanian water-bearing system (CWBS) is composed of two aquifers. The Lower aquifer consists of the flush type sediments and of marine washout sediments, which is characterized by coefficient of conductivity $4,3.10^{-5}$ $m.s^{-1}$. The Upper aquifer consists of marine friable sandstones with the hydraulic conductivity 7.10^{-6} $m.s^{-1}$. The flow of water is within pores and fractures. The CWBS is noted for a pressure regime for the whole Stráž block area, without the region (700 m broad) along the Lusitanian fault. The general flow direction of groundwater was coincident with the axis of the Stráž block from NE to SW till the start of uranium extraction and dewatering. The marlstones above the Cenomanian sequence belong to the Lower Turonian aquitard (thickness 80-100 m). The Middle Turonian aquifer (MTA) is mainly filled with medium - grained sandstones. Transmissivity of this is varied about $10^{-4}m^2.s^{-1}$. The groundwater flow is identical from NE to SW. The level in this aquifer is predominantly free in the whole area. The MTA is replenished by the infiltrated part of any precipitation and is used for the supply purposes by drinking water (total salinity 200-400 mg/l). The storages of groundwater were calculated at 565 l/s (5).

The infiltration into the CWBS only from outcrops of Cenomanian sediments was corrected with the water balance of the Hamr mine dewatering. It has been significant that the Stráž fault zone takes part in an infiltration from the Tlustec block. The differences of the piezometric heads between CWBS and MTA create the overflow from the MTA on the NE part of the Stráž block. A reverse groundwater overflow from the CWBS into the MTA can occur in the SW area behind the town Mimoň (Fig. 3,4). The average thickness of the whole Cretacesous sediments in the Stráž block is about 220 m.

The uranium deposits of the peneconcordant type with an unusual association of the elements: U-Zr-P-Ti have been occurred mainly within the lower part of Cenomanian sediments [2,6]. The uranium ore mineralization is concentrated into poorly permeable collectors in a chemical bond, which is very heavy for ISL. The economic thickness of this ore deposit has been used 5-15 m.

Uranium extraction and its impacts

The ISL project has been in operation for 27 years with pilot tests. The development of ISL fields in Stráž deposit was begun in 1970. Acid solutions were found out in mine water of the mine Hamr during two years. This state had been the result of the insufficient evaluation of the great hydraulic gradient (0,08-0,09) between the ore deposits Stráž and Hamr within the uniform hydrogeological structure (Fig. 2,3). The operational level in recharging boreholes within the leaching fields has been kept at the elevation 320-330 m o.s. and the elevation of a mine drainage must be kept up about 130-150 m o.s. At present the total volume of pumped mine water represents 508 $l.s^{-1}$including 345 $l.s^{-1}$ of acid mine water. The amount of acid solutions recharged into boreholes within ISL fields is 486 $l.s^{-1}$ and the discharge of these from boreholes is only 474 $l.s^{-1}$. The following chemicals were injected into the ISL fields in the last 25 years: 3,9 mil.t of H_2SO_4, 0,28 mil.t of HNO_3, 0,108 mil.t of NH_3 and 0,026 mil.t of HF [2]. The leaching process has been operated by 9 000 boreholes and pipelines for solution distribution on the surface with the length 25 000 km [3].

This acid solution procedure manifested itself by changes of a groundwater quality which are demonstrated in Table 1.

Table 1 Contamination of CWBS and MTA (adapted after P.Anděl 1991)

	ČSN standard for drinking water mg/l	acid solution mg/l	acid solution out of ISL fields mg/l	contaminated water in MTA mg/l
Be	0,0002	0,928	0,032	0,03
NH	0,5	1,270	150	1
As	0,05	13,55	0,9	
Ni	0,1	23,4	3,3	0,14
Cr	0,05	10,8	0,95	
F	1,5	237	100	1,8
V	0,1	12,1	1,6	
Mn	0,1	10		1,3
Cd	0,005		0,09	
pH	7,5	1	2	3
SO_4	250	$40-80.10^3$	3000	1500
Ra	Bq/l	Bq/l	Bq/l	Bq/l
tot.act.	0,1	1758	152	3

From this table we can see the conspicuous enhancement of the heavy metals contents from a recirculation of technologic solutions (only uranium is extracted).

The contaminants infiltrate into the MTA due to a standing high piezometric head in the CWBS along natural untightness through the Lower Turonian aquitard and mainly through badly plugged boreholes. During 1989-91 the observations revealed that contaminated area in the MTA with pH 4 had been spread inside the area with pH 5 within the ISL fields 9B (Fig. 5,4). At present this aquifer has been contaminated by 75 mil.cb.m. of acid water on the area 6 sq.km.

The area of ISL fields is separated from the area of mining by the so-called hydraulic barrier (HB) - i.e the line of boreholes, that is forming the artificial pressure watershed by means of the overpressure in boreholes (Fig. 3,2). This formed watershed should render some coexistence of both types of extraction. However the belated building up of the HB Stráž after 1972 came to the formation of hydrochemical influence of water in the CWBS between the Hamr mine and the area of ISL fields and spreading of solutions outside the ore deposit margin (Fig. 3,4). The technical measures to secure the coexistence of both extraction methods were never implemented in time (neutralizing station, HB Svébořice). The contemporary result of all measures is some steady hydraulic state, but without the regards to impacts on the environment e.g. HB Stráž has been used for a acid mine water deposition (240 $l.s^{-1}$).

The contemporary problem represents the new extraction strategy, from the mine company viewpoint, based on a lateral overacidification of new ISL fields No 26, 22 (Fig. 3,4). Inside the ZHP there were constructed pumping centres (PC 9-18 $l.s^{-1}$, PC 10 -24,2 $l.s^{-1}$). The activity of these is very danger for the quality protection of drinking water (pumped 70 $l.s^{-1}$ for supply). Any leakage of acid solution into the MTA means that discharged area will be closed for supply purposes. The negative impacts on the environment within the Stráž block and on the surface (deforestation for ISL fields, dustiness from mine dumps and setting pits, contamination of surface water) is undoubted and the liquidation of the chemical extraction must be initiated.

CONCLUSIONS

The onesided uranium extraction has been manifested itself by the extensive pollution of both the subsurface and surface environment, e.g. the river Ploučnice is contaminated by induced radivactivity a practically along all length including soils of flood plain from a dustiness along 30 km from Stráž [1]. Economically the extraction is expensive with a low effectivity owing to a very slow uranium leaching within poor permeable layers (three times longer time compared with assumptions). The liquidation of the extraction must be concentrated on chemical leaching which will take long time and great costs. The opinions on the liquidation we can divide in two parts:

a) a conservation of extraction with succesive protection measures;
b) the ecological examination, i.e. to stop a chemicals recharge into the ISL fields immediately.

From the hydrogeological viewpoint it must be prefer the second opinion owing to a groundwater storages protection which are renewable resources. The measures for the liquidation of chemical extraction are:

- to terminate the activity of PC inside the ZHP Mimoň, to check the artificial spread of acid solutions;
- to perform a recirculation of acid solutions inside the ISL fields and to increase the discharge of solutions from boreholes in relation to the recharge of these into boreholes;

- to decrease high piezometric heads within HB Stráž to prevent the acid solutions spread;
- to set values of all components in groundwater for both the aquifers, after the liquidation;
- to construct the profile for the contamination monitoring in front of the ZHP margin.

It is paradoxical that the structure - Stráž block creates a part of PANWA from 1982. The main purpose consists in the protection of groundwater quality and quantity for water management against negative man-made impacts into the landscape ecosystem.

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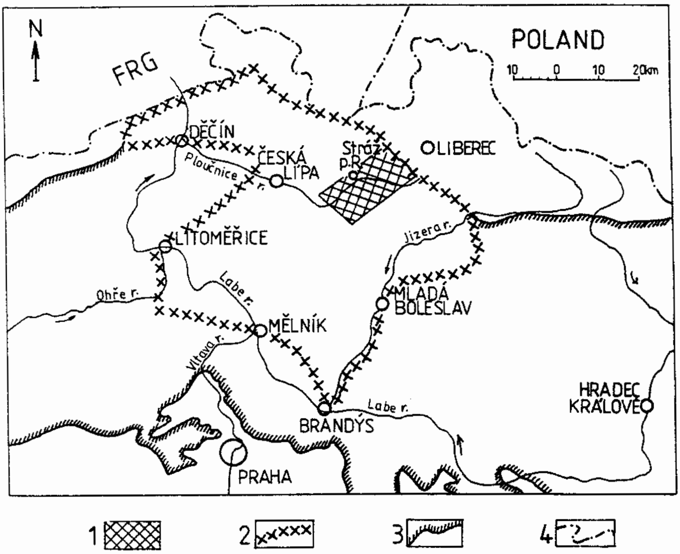

Fig.1 Position of the Stráž structural area within the preserved area of natural water accumulation - Northern Bohemian Cretaceous (adapted after J.Fiedler 1993). 1 - Stráž structural area (Stráž block); 2 - boundary of preserved area of natural water accumulation (PANWA); 3 - margin of the Czech Cretaceous Basin; 4 - state frontier.

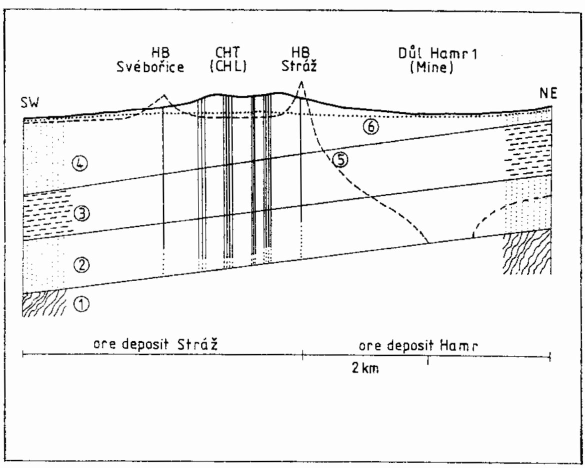

Fig.2 Schematic hydrogeological cross - section (adapted from J.Fiedler 1993).1 - crystalline bedrock; 2 - Cenomanian water-bearing system; 3 - Lower Turonian aquitard; 4 - Middle Turonian aquifer; 5 - piezometric surface of the CWBS; 6 - free level of the MTA.

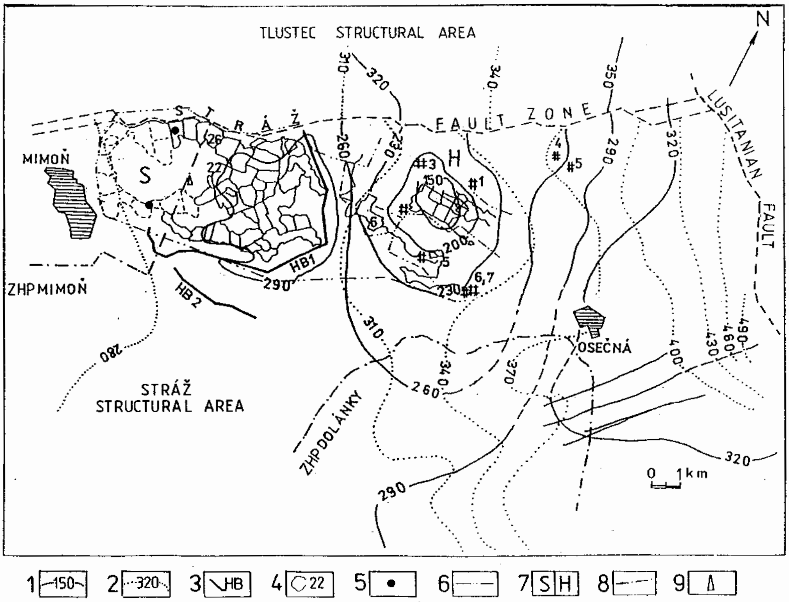

Fig.3 Scheme of hydraulic conditions within the ore deposit Stráž (adapted after data UM Hamr 1990-91). 1 - isopiestic lines of the CWBS; 2 - hydroisohypses of the MTA; 3 - Osečná basalt body within Cenomanian; 4 - the same within Turonian; 5 - zone of hygienic protection (ZHP); 6 - Ralsko hill; 696 m o.s.; 7 - pumping centre (PC); 8 - hydraulic barrier Stráž (HB 1), Svébořice (HB 2); 9 - boundary of mine field; 10 - operation number of ISL fields.

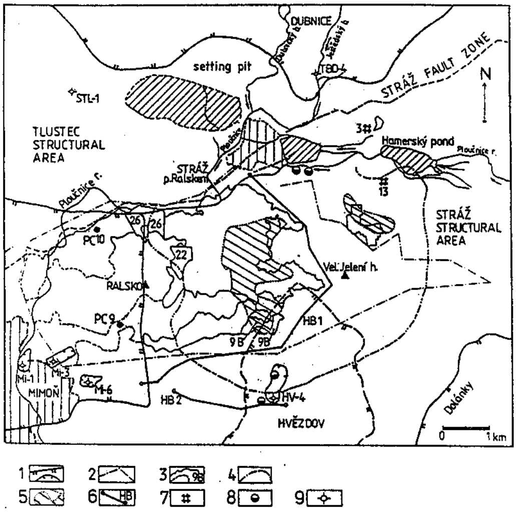

Fig.4 Map of zones of hygienic protection and areas of hydrochemical extraction within the Stráž structural area. 1 - zones of hygienic protection (ZHP) - 1st and 2nd stage; 2 - boundary of the hydrochemical extraction area; 3 - margin of ISL fields and operation numbers; 4 - contamination boundary within the CWBS; 5 - contamination boundary within the MTA; 6 - hydraulic barrier Stráž (HB 1), Svébořice (HB 2); 7 - shafts of the mine Hamr; 8 - contamination sites after Sowiet Army; 9 - pumping wells for drinking water.

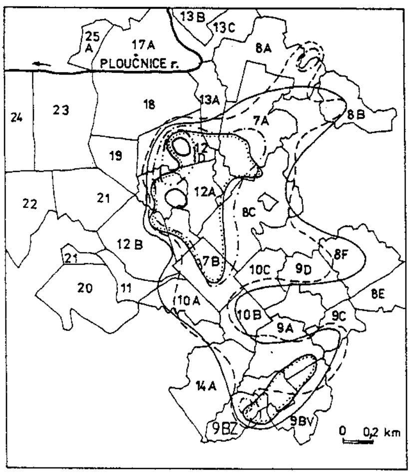

Fig.5 Changes pH within the MTA above leaching fields in time (after P.Anděl 1991) 9B-operation number of ISL fields; - - pH 5-1989; — pH 5-1991; -.- pH 4-1989; ... pH 4-1991; — pH 3-1989; -..- pH 3-1991.