

ENVIRONMENTAL REMEDIATION PROGRAM OF IN-SITU LEACHING URANIUM SITES IN THE CZECH REPUBLIC

Josef Tomas
Ministry of the Environment, Czech Republic

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ABSTRACT

The uranium ores have been mined in Bohemian Massif in different mining districts i.e. in West Bohemia, Příbram region and Middle Bohemia, Rožná district and in Stráž pod Ralskem district. The latter is represented by stratiform sandstone type of deposit where acid in-situ leaching has been applied as mining method since 1968. More than 4 mil tons of leaching acids have been injected to the orebearing sandstones. The area belongs to the nature area of water protection in North Bohemian cretaceous platform.

A complex evaluation of negative impact of uranium mining and milling in this area have been clearly articulated in Government Decrees Nos.:366/92, 429/93, 244/95, 170/96 and 427/97. A special declining regime of mining has been ordered and a remediation program has started to operate in 1996.

The uranium producer DIAMO s.e. prepared a Concept of Restoration of the area affected by in-situ leaching and an EIA according to the law No.244/1992 Coll., was executed. The Ministry of the Environment issued an Environmental Impact Statement which evaluated the condition of mining and restoration program in following steps:

1. Stop the input of leaching acids to the geological environment
2. Start to clean the polluted aquifers of underground water using evaporation station (Cenomanian) and membrane processes (Turonian)
3. Assess the surface pollution in the region especially the lithoral zone of Ploučnice River draining the area
4. Prepare a mathematic transport models of pollutants both in Turonian and Cenomanian aquifers
5. Monitoring the possible contaminated sites in the Stráž area and evaluate yearly the remediation progress

INTRODUCTION AND HISTORICAL REVIEW

The Bohemian Massif belongs to very important uranium bearing province. Uranium mineralisation has been connected with post-variscan hydrothermal activity and emplacement of carbonatic dikes with uranium mineralisation. Uranium ores have been mined in Jáchymov (Joachimsthal) since 1840, first for making paints and later when radium and polonium have been discovered by Mme Curie even for radium production. During the years 1907-1939 a total of 2,5 - 5,5 g of radium per year have been produced there.

The years 1945 - 1960 started the period of exploitation of uranium ores for army purposes and from uranium ore from Jáchymov the first Soviet atom bomb has been manufactured. A systematic exploration program including geological, geophysical and geo-chemical surveys and related researches, was carried out to assess the uranium potential of the entire country. Subsequently there have been opened and exploited following uranium districts :

West Bohemian District
 Příbram and Central Bohemian District
 Rozínka District
 North Bohemian Uranium District

Until the year 1999 a total of about 100,000 tons of uranium have been produced in all mines (about 20,000 tons from in-situ leaching fields).

Table 1: Uranium reserves in the Czech Republic (1996)

Locality	Tons of metal
Rožná	2400
Hamr	4400
Stráž	13400
Hvězdov	5000
Brzkov	1800
Total	22000

During the long period of underground mining especially since the end of II. World War a devastation of landscape by means of waste dumps accumulation, tailings and other workings have been enormous All these activities have a negative impact on the environment especially on surface and ground waters and soils.

In the mining districts of Jáchymov, Tachov, Horní Slavkov, Příbram there have been heaped more than 38 waste dumps of a large scale and many small waste dumps that originated during the extensive prospection period all over the Bohemian Massif.

Table 2: Land affected by waste dumps deposition

Region	Volume in thousands m3	Area in thousands m2
West Bohemia	10662	641
North Bohemia	1302	114
Příbram region	28511	1299
Dolní Rožínka	2623	406
Total	43107	2460

Table 3: Extent and volume of uranium tailings

Tailings	Extent in ha	Volume in thousands m³
Stráž pod Ralskem	187,0	19.236,0
Rožínka (GEAM)	90,1	9.827,4
MAPE Mydlovary	292,7	23.969,0
Příbram	44,1	238,3
Západní Čechy	20,1	2.798,0

URANIUM MINES IN THE CZECH REPUBLIC

The majority of uranium deposits in Bohemian Massif are vein type deposits but deposits we will pay an attention to are of stratiform, sandstone type and are situated in North Bohemian Cretaceous basin.

The North Bohemian area with its stratiform sandstone type of uranium deposits was the newest ore producing district in Czech Republic and its exploitation has started in 1969.

Because of relatively large deposit (about 200,000 t) the U-production was meant to cover all the long term needs of nuclear power plant supply, including export to former COMECON countries.

This situation has been changed dramatically after 1989 with the changes of political and economical situation in the whole Europe. The uranium spot prices in the world went rapidly down and the Czech uranium mines were not able to meet even the average of uranium prices on the world market.

The recession trend of mining production began with the collapse of Soviet empire when world wide nuclear disarmament program has started.

There have been taken government decisions to close down majority of uranium mines and the subsequent assessment of negative impacts of uranium mining on the environment have shown the necessity to install the remediation program of all areas where the uranium mines had operated.

GEOLOGICAL SETTING

Uranium concentration in Northern Bohemia occurs within sediments of the Upper Cretaceous platform unit of Bohemian Massif which are tectonically heavily affected and forming tectonic blocks. The most important concentration of uranium ores were found in s.c. Stráž block.

Cretaceous sediments have been deposited on metamorphosed basement consisting of low metamorphosed rocks and acid granitoids. Their sedimentary sequence range from Cenomanian to Turonian the latter one representing an important aquifer of drinking water.

The average thickness of the whole Cretaceous complex in Stráž block is about 220 m. The basalt volcanics of Tertiary age are penetrating the Cretaceous beds.

The stratiform uranium mineralisation is confined to the lowest part of Cenomanian beds (washout sediments) and has an unusual association of elements: U-Zr-

P-Ti (uraninite UO_{2+x} , ningyoite $(CaU(PO_4)_2 \cdot nH_2O)$, and hydrozircon $(Zr(Si_{1-x}O_{4.4x}(OH)_{4x}) \cdot nH_2O)$).

Two methods of mining have been applied within the Stráž block since the late 1960s:

a) Classical underground mining in Hamr mine. The stable water depression is still kept up by pumping out the mine waters at a rate of about $50 \text{ m}^3 / \text{min}$. The mining activity has ended in 1995 and since that year a back-filling remediation process has started (Gov. Decree No. 244/95)

b) The ISL has been in operation for 27 years (1969-1996) and so far 32 ISL claims have been commissioned covering a total area of about $600\,000 \text{ m}^2$.

NEGATIVE IMPACT ON THE ENVIRONMENT

After 1989 the political and economical situation in Europe has changed dramatically and finally attention has been paid to the evaluation of negative impacts of extensive mining activities on the environment of the Czech Republic.

In the Bohemian Massif the main impact of mining is in North Bohemian brown coal basins, than in North Moravian Ostrava pit coal basins and last but not least in the areas of uranium underground mining and in-situ leaching. The Czech Government has paid serious attention to the restoration programs followed by remediation of the areas affected by the uranium mining and milling.

The environmental issues connected with uranium mining can be listed as follows:

- old uranium mines and mills
- old uranium mines waste dumps
- waste dumps left after uranium exploration
- tailing in-poundments

Government Decrees have been taken to close down all uranium underground mines except the Rožínka Mine (Czech-Moravian Highland) and the subsequent assessment of negative impacts of uranium mining and milling on the environment has shown the necessity to start with a wide remediation program of all environmental issues connected with uranium mining as listed above.

The uranium mines in Hamr and Stráž pod Ralskem were chosen as the first heavily affected area for the restoration program because in-situ leaching method and underground mining were operating together there in one geological unit i.e. Cretaceous Cenomanian sandstones. The mining activities, especially in-situ leaching were influencing ground water regime and the pollution is enormous.

A quantity of 3.8 mil. tons of H_2SO_4 , 270 000 tons of HNO_3 and 103 000 tons of NH_4 have been injected into the leaching fields of the Stráž deposit in the last 25 years. This has affected a total of 188 mil. m^3 of Cenomanian underground water over an area of 28 km^2 .

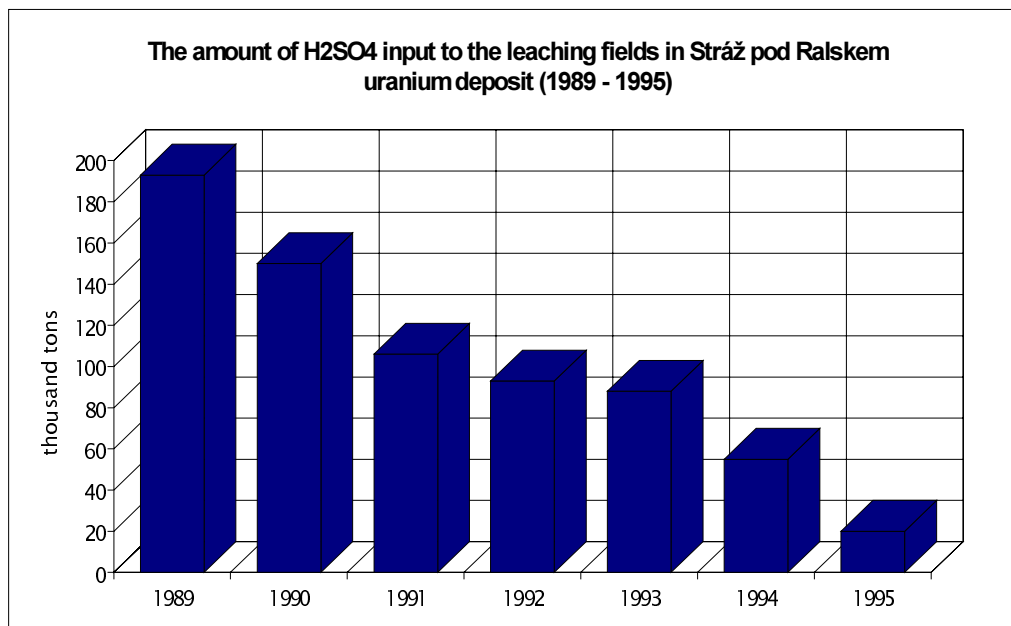


Figure 1: The amount of H₂SO₄ input to ISL fields

Leach solutions from ISL fields have dispersed horizontally and vertically not only to the Cenomanian horizon but along the extraction boreholes and tectonic lines to the Turonian drinking water aquifer.

To solve the negative influence of coexistence of Hamr mine and ISL Stráž mine a protective hydraulic barrier has been built between these two deposits.

According to hydrogeological investigation and hydrological modeling of water and acid solutions the first steps have been already executed. Circulation water from Hamr mine is pumped out in a quantity of about 50m³/min. and forced into the Stráž hydraulic barrier. This will make a steady overpressure in the SW part of the Stráž block behind the hydrological barrier.

Solving the hydrogeological situation, to suppress above mentioned negative impact of ISL on the environment the construction of a desalination plant with a capacity of 5m³/min has been projected. These technologies started to operate in 1996 and the first positive results were achieved.

ENVIRONMENTAL REMEDIATION PROGRAM

Knowing about this very serious problem the Czech Government has approved an environmental restoration program already in 1992 with broad declining uranium mining regime. The following Government Decrees have been issued regarding this problem:

No.366/1992 - Complex evaluation of chemical mining in North Bohemian area. A program for closing ISL and remediation of uranium mines.

No.429/1993 - Concept of the recession program of underground mine Hamr

Government Interministerial Commission of Experts have been established to help the uranium producer DIAMO a.s. to analyse the problem, to design the methods of restoration of ISL, to supervise the process and to control the executing of the program stated in the Government Decrees.

The analysis of problems connected with the evaluation of the environmental impact of uranium mining has provided a complex set of data dealing with this problem. The main contractor of the project is the uranium mining company DIAMO a.s. together with co-operating institutions (e.g. MEGA a.s., Aquatest a.s., Universities). The financing of restoration program is covered by state budget with international support (EC, PHARE, Dutch Government, Danish Government, IAEA). The analysed problem is unique in all Europe in its size and timescale.

No. 244/1995 - Realisation of restriction of uranium mining and milling in the Czech Republic. It states the duty to close from 1.5.1995 the underground mine Hamr and start its back-filling. It states also the duty to design the clear concept of the future restoration program which have to be financed from the state budget.

No. 170/1996 - to the final report about the remediation of the chemical extraction of uranium in Stráž pod Ralskem. It announced the end of ISL from 1 April 1996 and the duty for the Ministries involved to submit each following year the progres report about the remediation program.

No. 427/1997 – to the liquidation of the last uranium underground mine Rožná starting with the year 2002.

TECHNOLOGIES RECOMMENDED FOR THE RESTORATION OF THE ENVIRONMENT

A technology of thermal thickening by evaporation followed by dressing of concentrated components was chosen for the decontamination of strongly saline Cenomanian waters (up to 200g/l). It is expected that a volume of 5 m³/ min. will have to be pumped out from this aquifer. For the decontamination of slightly polluted water from the Turonian aquifer a volume of about 2 - 3 m³/ min. has to be cleaned using membrane processes. An evaporation station has been built by RCC (USA) and started to operate in 1996.

Technological decontamination of polluted waters is divided in two basic stages:

I.stage - thermal thickening in evaporation station with separating of uranium and injecting the thickened solutions back to the Cenomanian aquifer with the aim to reduce the extend of salinated liquids in the geological environment. This stage is expected to operate till the year 2000.

II.stage - separation of precipitated salts from the concentrated solution and dressing of separated salts focused on the commercial use of final products. The technological unit which will be attached to the evaporation station will be based on further multigrade crystallisation and final dressing of products. These are namely

aluminium-amonium sulphate and remaining constituents the latter supposedly transformed by calcination into insoluble waste for safe storage. The remediation process will last according to the model calculation till 2032.

ENVIRONMENTAL IMPACT ASSESMENT

As an independent part of the Final Report prepared for the Czech Government the EIA which evaluated not only the negative impact of uranium mining and milling on the environment but as well the activities proposed by DIAMO s.e. as designed restoration program has been concluded.

The Ministry of the Environment issued according to the law No.244/1992 a statement where all the conclusions and comments have been formulated.

THE STATEMENT OF THE MINISTRY OF ENVIRONMENT

The Ministry of the Environment taking in consideration all the materials regarding the restoration program of the area affected by uranium in-situ leaching in Stráz pod Ralskem agreed with the concept of remediation program and EIA submitted to the Ministry of the Environment within the following conditions:

The first stage of the remediation program will start on the 1st January 1996 and will be followed by the operation of the evaporation station to stabilize and control the leach liquors in the Cretaceous aquifers. This stage represents the beginning of the complex program of restoration of the environment in the whole area. Uranium extraction from the leaching fields will continue as subordinate process of restoration program.

At the same time the monitoring system will be modified according to the results gained to assure the system will register the effectivity and progress of the restoration process. The restoration steps will be coordinated with the liquidation of the Hamr underground mine and tailing impoundments in the Stráz region. Simultaneously the geochemical contamination of the surface sediments and waters along the river Ploucnice will be solved.

The recultivation of the surface will be coordinated with the technological regime of rehabilitation and parts of natural reservation (Ralsko, Velký a Malý Jelení vrch, Lipka) will be respected as the systems of ecological stability.

DIAMO s.e. will arrange a complex socio-ecological study which will consider the program of revitalisation of the area.

Taking in consideration the difficulty of the problem The Ministry of the Environment requires from DIAMO s.e. to accomplish:

1. A complex analysis of the critical parts and risk assessment of the proposed concept of remediation program with special attention to the contamination of the Turonian aquifer.
2. A report on the possibility of immobilization of the contaminants underground in the Cenomanian aquifer as an alternative program in the last stages of decontamination.
3. To define and prepare a follow-up project dealing with the products of the evaporation station extracted from underground and particularly dealing with the remaining constituents (incl. radioactive wastes).

4. Simultaneously conduct processes to produce materials which will be suitable for further technological use or for sale. Products (minerals) possible for reuse have to be safely stored.
5. To prepare the study regarding the minor elements content which have been enriched during the circulation of salinated liquids underground (REE, Al, Be, Ni etc.) as future non-traditional mineral resources.
6. To evaluate the content of radioactivity and radionuclides in the liquors and evaporation station products especially in final calcinate.
7. Prepare a broad research program and follow up studies with the aim to finalize the technological program and verification of executed steps.

SUMMARY

The above described program of uranium mining and milling remediation is enormous in the extent, time scale and financial demands.

After the three years of remediation and monitoring of expected and reached results there the mathematic models have been prepared both of the pollutants transport and progress of the results expected using designed restoration technologies.

With regards to the fact that in the area of Stráž pod Ralskem affected by above described activities there exist independent large scale environmental issues, i.e. underground mine Hamr and its liquidation, in-situ leaching of uranium and tailings the remediation steps and results could be conclude as follows:

1. After the back-fill the underground mine Hamr will be flooded by surplus alcalised tailing waters (pH 7-8). This will resulted finally to cancel the hydrological barrier built between underground mine and ISL fields
2. The remediation of tailings is progressed according to the independent project and Ministry of the Environment issued an Environmentalk Impact Statement and agreed with the process sub 1.
3. The evaporation station started to operate in 1996 and so far the Cenomanian underground water level was lowered for about 10 m assuring that the pollutants will not influence the upper Turonian drinking water aquifer. In 2000 first 50 000 tons of products will be put on the market (mainly aluminium sulphate). According to the model calculation the remediation process of ISL fields will end in the year 2032.

It is necessary to say that the progress of remediation program is involved by the possibility of state budget so the next year with the slight financial recession will slow it remarcably down.

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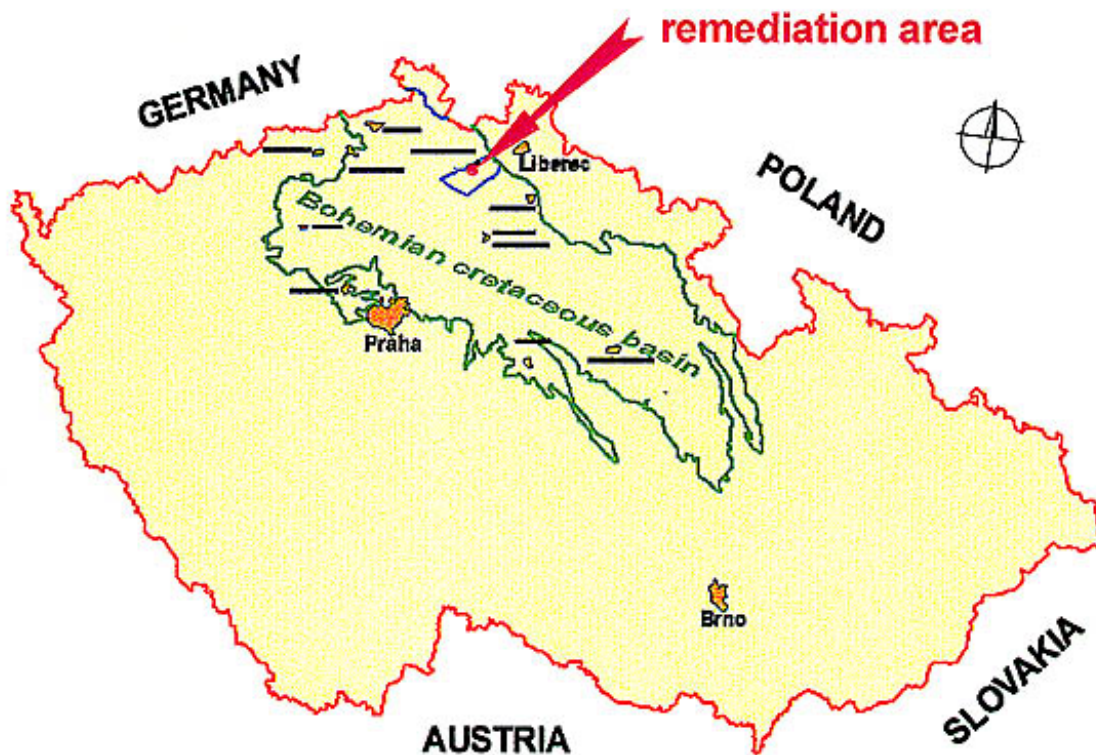
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CZECH GOVERNMENT Decrees Nos. 366/ 1992, 429/ 1993, 244/ 1995, 170/1996, 427/1997

Explanation of Figures:



Dr. Josef Tomas: Environmental Remediation Program of In-Situ Leaching Uranium Sites in the Czech Republic

Fig. 2: The Stráž block Situation within the Territory of the Czech Republic

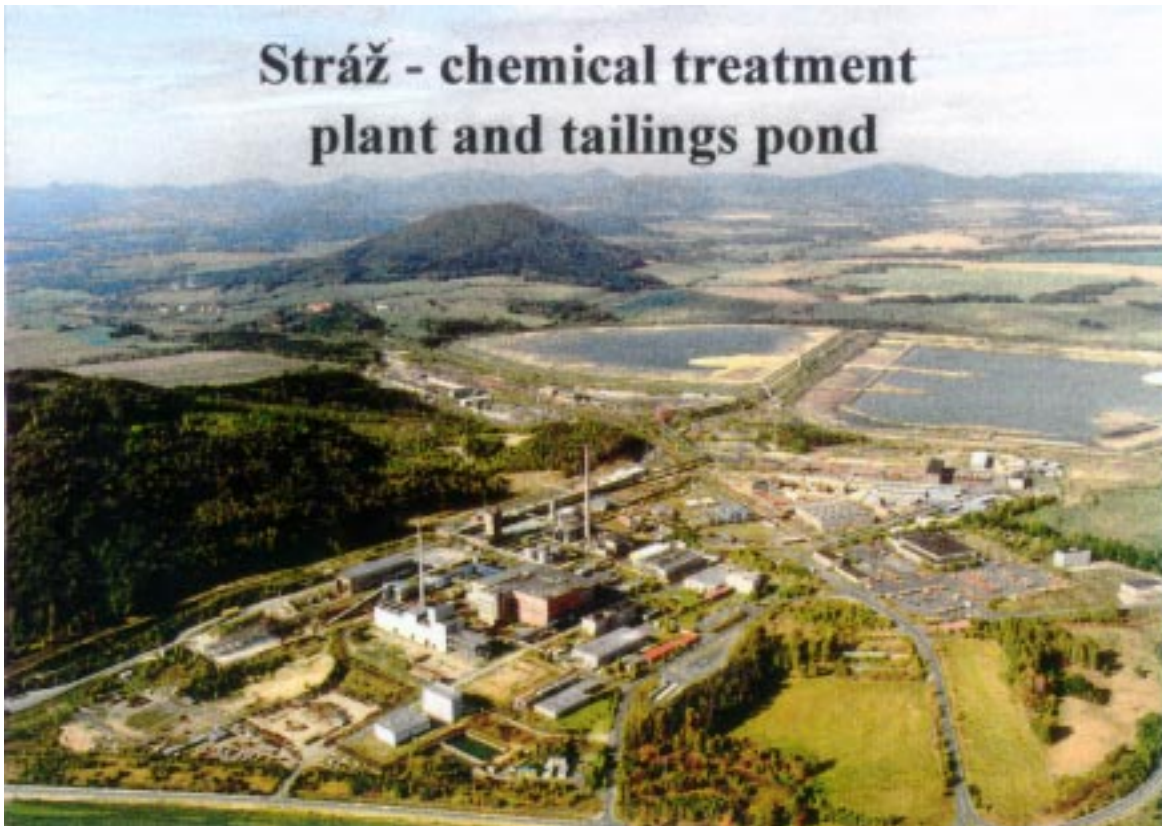


Fig. 3: Stráž – chemical treatment plant and tailing pond



Fig. 4: Stráž – leaching fields

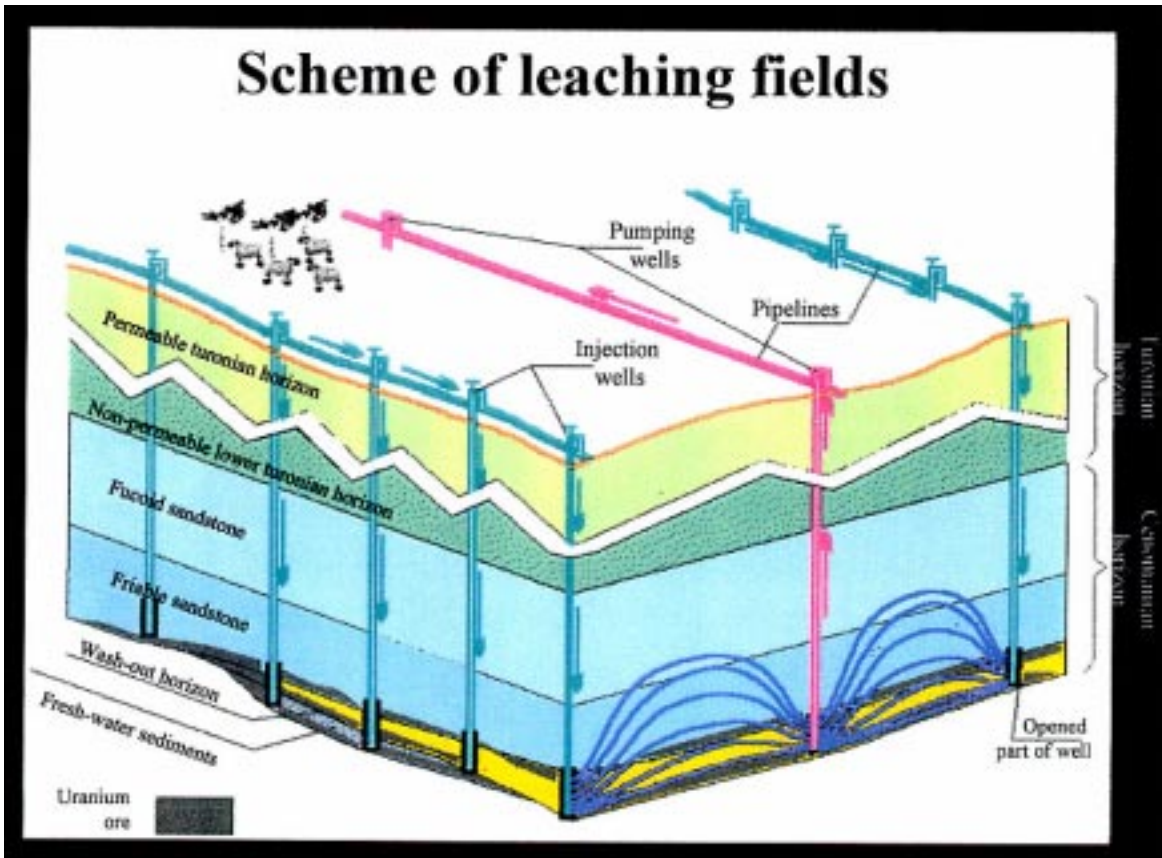


Fig. 5: Scheme of leaching fields