MINE WATERS OF THE FLOODED URANIUM DEPOSIT IN OLŠÍ

DŮLNÍ VODY ZATOPENÉHO URANOVÉHO LOŽISKA OLŠÍ

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Abstract

After abandonment of underground uranium mines, it is necessary to ensure the safe use of mine waters accumulated in flooded mines, because they contain uranium, radium and other contaminants in high concentrations and may thus, in the case of uncontrollable release from flooded mines, endanger their surrounding environment. On the other hand, with regard to their considerable volume, these mine waters represent a secondary source of uranium. In this paper the author reports on the use of mine waters after mining operations in the Olší deposit were finished and on methods of mine water treatment. He also deals with the possibilities of producing uranium as a secondary product in the course of mine water treatment.

Abstrakt

Po ukončené likvidaci hlubinných uranových dolů je nutné zajistit bezpečné nakládání s důlními vodami akumulovanými v zatopených bývalých dolech. Tyto důlní vody totiž obsahují ve vysokých koncentracích uran, radium, případně další kontaminanty a mohou tedy v případě nekontrolovatelného úniku ze zatopených dolů ohrozit životní prostředí v okolí. Současně však představují důlní vody zatopených bývalých uranových dolů, vzhledem k jejich značným objemům, druhotný zdroj uranu. V příspěvku autor informuje o nakládání s důlními vodami po ukončení těžby na ložisku Olší a o způsobech jejich čištění. Zabývá se možnostmi produkce uranu jako doprovodného produktu při čištění důlních vod.

Key words: flooded mines, mine waters, uranium concentration, quasi-stagnant regime.

1 INTRODUCTION

The deposit of Olší was mined between 1959 and 1989. At the time when the exploitation of this deposit ceased, the mining operations were at depths below level 10 (+18 m above sea level, i.e. 467 m below ground level) and the deposit was opened by a blind shaft as deep as the 18th level (374 m below sea level, i.e. 859 m below ground level). Ore bodies of the Olší deposit were characterised by their irregular shape, variable thickness and uranium content. Small and medium-sized bodies developed and were predominant on levels two and three. With depth, the size of ore bodies diminished and the coefficient of mineralisation decreased as well. The richest ore bodies were localised on levels 2 to 5 of the deposit. Generally it can be stated that the ore bodies had complicated internal structures; ore mineralisation in them was non-continuous and occurred in irregular ore lenses and layers [1].

In this locality, the progress of mining operations and mine drainage, the geological structure of the deposit, the hydrology and hydrogeology of the area and also of the mine and the hydrogeochemical regime of mine waters are all well documented. The deposit is found in crystalline complex rocks, with the uranium deposit in the metamorphic sedimentary-effusive rocks of the Precambrian. The proper rocks of the deposit composed of biotitic to amphibolic gneisses of various degrees of migmatisation and amphibolites, range from low permeability to impermeability. This fact determined the hydrological outflow parameters in the framework of the deposit. The Olší deposit is largely drained by the Hadůvka creek running into the Loučka River, with the smaller northern part being drained by the Teplá creek into the Nedvědička River.

2 MINE WATERS OF THE OLŠÍ URANIUM DEPOSIT

The basic data on conditions in the Olší deposit, after finishing the exploitation of the deposit, are given below.

- The spontaneous flooding of the underground mine in the Olší deposit began in April 1989 after its exploitation had ended. The volume of mine waters accumulated underground is about 2.3 million m^3.
- The chemistry of mine waters changed during the development of mining (which increased the volume of mined-out cavities), and the initial concentrations of substances in the water diminished.
- This effect was caused by the creation of preferential directions of communication between surface water and the underground part of the mine as a result of the reduction in groundwater level in the centre of depression, thus increasing the velocity of groundwater flow towards the point of pumping (the washing out of the whole zone of weathered parts of the deposit did not occur). When the mine water ceased being pumped and backfilled, the mining-affected parts of the deposit started to flood. The mine waters were enriched with highly-soluble compounds that had previously been dried and exposed to oxidation during the exploitation of the deposit.
- For the controlled use of mine waters (drainage of excess water from the flooded mine) a drainage adit was driven and a mine water purification plant was built at its exit.
- In January 1996, mine waters rose to 451.3 m above sea level (the floor of the drainage adit).
- Since 1996, the purification of excess mine waters pumped and drained through the drainage adit from the deposit has taken place. The purified mine waters have been discharged into a surface stream (Hadůvka stream).
- Since 1997, the mine water level has been maintained by pumping at levels of 1.5–7.0 m below the overflow level (the floor of the drainage adit), i.e. at a level ranging from 449.8 to 444.3 m above sea level. Therefore, contaminated mine waters will not infiltrate spontaneously and without control into the surroundings. The quantity of mine waters treated annually in the deposit of Olší amounts to 200 000 – 280 000 m^3. During mining operations, the maximum pumped quantity of mine waters was recorded in the years 1981 and 1986, and amounted to about 17.0 $L.s^{-1}$.
- The average content of uranium in waters pumped and drained from the flooded deposit through the drainage adit to the water purification plant has gradually decreased from 11.7 mg/L in 1996 to 5.9 mg/L at present.

Monitoring the quality of mine waters at the Olší deposit was prescribed by mining regulations and over the course of mining the sampling points were situated in shafts Olší (O–1) and Drahonín (O–4). The waters were mixed waters of Ca (Mg) - SO_4 - HCO_3 type with a temperature of about 8 to 10°C (depending upon the season, distance from the shaft and depth below the surface). At present, mine water is monitored before entry into the purification plant and after purification, i.e. the water discharged into the watercourse. The progress of change in the chemical composition of mine waters of the deposit after flooding is documented in Tables 1 and 2. However, these changes are changes in the upper part of aquifer, not in the whole deposit.

Tab. 1 Chemical composition of mine waters in the period of exploitation of the Olší deposit (by 1989) [2]

		Shaft Olší (O-1)	Shaft Drahonín (O-4)
pH		6.50 – 6.90	6.50 – 6.80
Residue at 105°C	$mg \cdot l^{-1}$	750.00 – 960.00	740.00 – 1050.00
Ca^{2+}	$mg \cdot l^{-1}$	29.50 – 169.60	22.40 – 226.40
Mg^{2+}	$mg \cdot l^{-1}$	18.40 – 78.20	26.50 – 96.60
Fe^{2+}	$mg \cdot l^{-1}$	2.20 – 4.80	0.20 – 3.00
Cl^-	$mg \cdot l^{-1}$	18.70 – 46.30	15.90 – 36.50
SO_4^{2-}	$mg \cdot l^{-1}$	338.20 – 1152.00	126.70 – 1388.40
NO_3^-	$mg \cdot l^{-1}$	1.960 – 92.50	1.96 – 105.30
CO_3^{2-}	$mg \cdot l^{-1}$	38.60 – 114.00	49.10 – 110.20
HCO_3^-	$mg \cdot l^{-1}$	115.90 – 170.90	128.10 – 347.80
O_2	$mg \cdot l^{-1}$	5.30 – 11.80	5.20 – 12.20
U	$mg \cdot l^{-1}$	0 – 4.46	0 – 2.45
Ra^{226}	$Bq \cdot m^{-3}$	0 – 1150.00	0 – 860.00

Tab. 2 Chemical composition of the mine waters from the flooded Olší deposit entering the purification plant between 1996 – 2006 (* only results from one sample)

		Entry to purification plant		Exit from purification plant
		Min – max	Average	Average
pH		6.10 – 7.52	6.92	7.64
Ca^{2+}	$mg \cdot l^{-1}$	350.00*	-	not observed
Mn^{2+}	$mg \cdot l^{-1}$	1.43 – 8.71	4.55	1.00
Fe^{2+}	$mg \cdot l^{-1}$	2.33 – 18.85	9.79	0.20
Cl^{-}	$mg \cdot l^{-1}$	27.00*	-	not observed
SO_4^{2-}	$mg \cdot l^{-1}$	871.10 – 1843.90	1390.64	1100.00
NO_3^{-}	$mg \cdot l^{-1}$	1.00 – 12.00	4.37	not observed
HCO_3^{-}	$mg \cdot l^{-1}$	560.00*	-	not observed
U	$mg \cdot l^{-1}$	5.26 – 13.10	9.20	0.05
Ra^{226}	$Bq \cdot m^{-3}$	110.00 – 2700.00	1225.10	80.00

The declining trend in the uranium concentration of mine waters drained through the drainage adit from the flooded Olší deposit is completely logical, because in the upper part of the aquifer, a so-called shallow circulation of mine waters, there is a significantly higher proportion of waters infiltrated from atmospheric precipitation or infiltrated from surface watercourses. Thus this trend is not representative for the uranium content in the aquifer of accumulated waters in abandoned mine workings as a whole. Within the terms of the research we have been conducting, just those waters accumulated in deeper parts of the former mine, in a so-called quasi-stagnant regime, form the environment of interest. The extent of shallow circulation depends on the hydrogeological conditions and the method in which the deposit was developed, as well as the flow of waters induced by controlled drainage of mine waters (either by pumping or by gravity); whereas quasi-stagnant waters are impounded in the mine, almost without movement, and the concentration of dissolved substances is markedly higher than in the shallow circulation waters [3].

3 MINE WATERS IN THE DEEPER PARTS OF FORMER MINE

The verification of properties (chemical composition) of mine waters accumulated in abandoned mine workings after flooding the underground mine, represents a serious technical problem. Mine waters are impounded in the former mine and the single permanently accessible point to sample and analyse them is the point of controlled drainage of waters from the mine. However, at this point these waters are more or less waters of shallow circulation having other properties and composition in comparison with the waters accumulated in deeper parts of the former mine.

One possibility for acquiring data on the composition of mine waters outside their shallow circulation is represented by shafts, provided that they have not been fully backfilled as part of the mine's decommissioning, and providing that they have remained accessible for the sampling of waters at various depths even after the mine was flooded. With regard to former uranium deposits, so far only some shafts in the Příbram deposit have been accessible and suitable for taking the samples of waters. Here, the properties of mine waters have been observed in this way periodically since 2004 [2], [4]. But results obtained in this way still do not necessarily represent the typical characteristics of mine waters of the given deposit. Shafts are usually situated in the underlying layers of the deposit and not in parts of the deposit exposed to intensive mining activities, i.e. outside those areas where, even after previous exploitation, non-mined parts of ore bodies have remained to be exposed to oxidation. Instead they primarily represent a drainage system through which surface and near-surface waters are brought to the former mine, causing changes in the properties of mine waters accumulated in the shafts and their near surroundings.

The only possibility for obtaining a representative sample of mine waters impounded in the deeper parts of the former mine is a borehole drilled from the surface to the mine working in the central part of the deposit and outside the expected area of active drainage of the flooded mine. In the Czech Republic, such a hydrogeological borehole was drilled in the Olší deposit for the first time as part of the GAČR research project No. 105/06/0127 [5], [6].

The research hydrogeological borehole is located 375 metres northwest of the former shaft O–4. It passes through the complex of overlying rocks consisting of amphibolites and biotitic gneisses, and below level 3 of the former mine (about 160 metres below ground level) reaching earlier extracted vein structures. It passes outside mine workings that serve the active drainage of the former mine. Its mouth is located in the mine working on level 5, i.e. at a depth of 245 metres below ground level. The borehole is lined for its whole length: in the 0–9 m interval it has a diameter of 324 mm, in the 9–165 m a diameter of 219 mm and in the last part – in the 165–245 m interval – it has a diameter of 108 mm. At water inflow points into the borehole, the lining is perforated which is the case at the intervals 169.16–180.53 m, 203.39–220.82 m and 233.14–245 m. During drilling, a core was taken from the 173–175 m and 177.2–181.7 m depth intervals to study geochemical changes in the rocks of the abandoned and flooded deposit.

After completing the borehole, the pumping test was performed in two stages. The purpose of the pumping test was partly to verify the stability of inflows, but mainly to determine the chemical composition of mine waters at specific levels, where inflows of mine waters into the borehole had been captured. In the first stage, the pump was lowered to the depth level of 210 metres, whereupon the actual pumping test took place from 24 July 2007 to 31 July 2007. The other stage of the pumping test was performed from a depth of 170 metres, and took place from 31 July 2007 to 2 August 2007. Water samples were regularly taken for chemical analyses. With regard to the research project’s objectives, the hydrogeological borehole, or more specifically the pumping test, has confirmed the assumption that an accumulation of mine waters with uranium content suitable for utilisation as a secondary source of this raw material exists in deeper parts of the former mine. Whereas in the period of exploitation the concentration of uranium in mine waters did not exceed 4.5 mg/L, after flooding the mine, the concentration of uranium in waters of shallow circulation increased to an average of 9.0 mg/L, but thereafter exhibits a declining trend (at present the concentration of uranium does not exceed 5.9 mg/L). After stabilisation of the water regime, an uranium concentration of 17.5 mg/L was however determined in quasi-stagnant waters outside the zone of active draining.

4 THE UTILISATION OF QUASI-STAGNANT MINE WATERS AS AN URANIUM SOURCE

To verify whether or not the utilisation of quasi-stagnant mine waters as a secondary uranium source is viable, a pilot scale test has been prepared in the Olší deposit. As a site for pumping mine waters with a high content of uranium, the hydrogeological borehole is used. From the pumped waters, uranium is separated using the technology of sorption on the ion exchange resin. Because the proposed technology does not remove any other contaminants from mine water, the water is subsequently injected at another point back into the deposit. The operation of active drainage of the flooded former mine through the purification plant is not and will not be changed in any way. Ongoing changes in the chemistry of mine waters, i.e. both quasi-stagnant waters pumped from the borehole and those in waters of shallow circulation before entering the purification plant, will be continuously observed. The presented engineering solution will not change the present state in relation to the surrounding environment; all changes in mine water circulation take place merely inside the flooded deposit [7], [8], [9].

The pilot scale test is designed for pumping 10 L/s of mine waters from the hydrogeological borehole 300 days a year, i.e. at all times except during the winter months, because any heating of the sorption station has not yet been considered. The same amount of mine waters is injected back by the injection borehole into the deposit. The injection borehole is situated about 600 metres north of the pumping (hydrogeological) borehole; its depth is 27 metres and it leads to mine workings on level 1 that are not flooded. It can be expected that due to the induced circulation of quasi-stagnant waters the content of uranium in these waters will diminish from the present value of 17.5 mg/L to lower values, at the average of about 15.0 mg/L. For these parameters, the theoretical yield of uranium is 3888 kg per year. For comparison, 1130 kg of uranium as a purification by-product was obtained in 2008 through the operation of the mine water treatment plant.

Providing that it will be possible to utilise quasi-stagnant waters for about 10 years before any marked drop in the content of uranium, the total yield will be 30–35 tons of uranium at the expected permanent moderate decrease of uranium concentration.

The pilot scale test for utilisation of quasi-stagnant waters with a high content of uranium will provide a necessary basis for the next theoretical works (mathematical modelling of flow and transport of substances in the flooded mine) and simultaneously will serve as verification for theoretical findings.

5 MATHEMATICAL MODELLING APPLICATION

Mathematical modelling application used for this project is highly demanding, due to the high level of uncertainty and a minimal amount of calibration data, with regard to the water quality at various levels and/or flow rates within the simulated structure. That is why it is necessary to base the model solution on a reliablycalculated water balance for the deposit. It is assumed that the mine's sole source of recharge is precipitation. Therefore, it is essential to determine the hydrologic balance of the partial river catchment area correctly; i.e. direct run-off (overland and overburden run-off), evapotranspiration, and effective infiltration into the modelled structure [10], [11].

The undisturbed rock mass usually has an interstitial or dual (interstitial-fissure) type of porosity. Commonly used models of groundwater flow do not enable any hydraulically-correct simulation of dual porosity. As soon as the rock mass is mined, the workings create free spaces with a karst type porosity, so that flow patterns and rates are determined by secondarily produced, hydraulic inhomogeneities, and anisotropic environment. The main problem in the simplification of this type of environment (anthropogenic pseudokarst) is to describe changes in the hydraulic properties of preferential flow paths.

The project underway at the former, already flooded, uranium mine in Olší requires the application of a modelling code that could simulate double porosity flow as well as preferential flow along mine workings.
The FEFLOW code was selected as the best available software due to the flexibility of finite elements mesh design to enable the geometrisation of the uranium ore deposit to an acceptable level of simplification. In addition to 3D elements, it is possible to work with a combination of planar and linear elements applicable for the simulation of fractures as well as vertical and horizontal mine workings. Within these elements, there is a choice of hydraulic calculations based on Darcy's law for porous media, the Hagen-Poiseuille law for fracture flow, or the Manning-Strickler law for channel flow. The problem in conceptualisation and modelling of the mining environment consists in a correct description and quantification of the hydraulic properties of preferential pathways. Depending on the site, one can decide to use either the Darcy or Manning-Strickler equations for mine workings. A three-dimensional model of mine workings was built for the Olší Mine using the geographic information systems (GIS).

As stated earlier, it is assumed that the deposit is recharged only from precipitation. Much of this water remains in shallow circulation and drains into local streams, while only a part of the groundwater reaches the deeper parts of the deposit to flow along preferential pathways, mine workings and some fractures. The groundwater level in the deposit is kept at a specified level by pumping. In order to validate those two components of groundwater circulation, the hydrological balance of the partial watershed has to be assessed carefully. The rainfall run-off model HEC-HMS and water balance model HELP (Hydrologic Evaluation Landfill Performance) are being used for this purpose.

In spite of the problems and uncertainties involved in applying groundwater modelling to mining problems, the modelling can play an important role in solving complicated mining hydrogeological tasks. The groundwater modelling, based on realistic assumptions of hydrogeological structure, boundary conditions, recharge and discharge areas, is a valuable tool for verifying the validity of conceptual models. Mathematical modelling is the only applicable tool to assess the impact of hydraulic stresses (and especially their interference) on aquifers. The modeller must be aware of specific features of groundwater flow in the environment disturbed by mining activities, and must apply such knowledge in an appropriate way in his modelling study.

6 CONCLUSION

After sufficient verification in the Olší deposit, it will be possible to apply the principle presented here to practically all uranium deposits that have been exploited by underground mining and where non-backfilled empty cavities, which have facilitated the origin of quasi-stagnant waters, have been left after exploitation. The specific engineering solution, especially the method of quasi-stagnant water pumping, must however rest on the conditions of the given deposit, its geological structure, hydrogeological conditions, the method of development and exploitation as well as how the mine was decommissioned.

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REFERENCES

[1] Team of authors, *Rudné a uranové hornictví České republiky (Metalliferous and Uranium Mining Industry in the Czech Republic)*, Ostrava: ANAGRAM, 2003. 647 pp. ISBN 80-86331-67-9.

[2] HÁJEK, A., LUSK, K., VŠETEČKA, M. & VESELÝ P. *Analýza zaplavování uranových dolů v České republice (Analysis of flooding the uranium mines in the Czech Republic)*, Archives of Diamo s. p., 2006, PP. 171 and suppls.

[3] GRMELA, A. & RAPANTOVÁ, N. *Specifika hydrogeologického režimu ložisek v období těžby a po jejím ukončení.* Konference „Těžba a její dopady na životní prostředí“ , Lísek - Skalský dvůr, 2006, Vodní zdroje

[4] MICHÁLEK B., HÁJEK, A. & GRMELA, A. *Closure of Uranium Mines in the Czech Republic*. Mezinárodní konference Mine Planning and Equipment Selection (MPES 2005 and CAMI 2005). Banff, Kanada, 2005. CD ISSN 1712-32-08.

[5] MICHÁLEK, B., HÁJEK, A., RAPANTOVÁ, N. & GRMELA, A. Výzkum důlních vod uranového ložiska Olší-Drahonín, *Uhlí, rudy, geologický průzkum*, 2007, LV, Nr. 12, pp. 11-15. ISSN 1210-7697.

[6] MICHÁLEK, B., HÁJEK, A., ZÁBOJNÍK, P., RAPANTOVÁ, N. & GRMELA, A. *Research on Mine Waters of Closed and Abandoned Uranium Mines*. "5th International Conference on Uranium Mining and Hydrogeology", Freiberg, Germany, 2008.

[7] MICHÁLEK, B., RAPANTOVÁ, N., GRMELA, A. & HÁJEK, A. *Mine Water of Abandoned Uranium Deposits as a Utilizable Uranium Source*. III International Seminar on Mine Closure –MINE CLOSURE 2008, 2008, pp. 587-598, Johannesburg, South Africa. ISBN 978-0-9804185-6-9.

[8] MICHÁLEK, B., HÁJEK, A., LUSK, K., VESELÝ, P. & GRMELA, A. *The Use and Treatment of Mine Waters from Closed and Flooded Uranium Mines*. Conference “Securing the future”, 2009, Skelleftea, Sweden. In: http://www.proceedings-stfandicard-2009.com/

[9] RAPANTOVÁ, N., GRMELA, A., MICHÁLEK, B., HÁJEK, A., ZÁBOJNÍK, P. & ZEMAN, J., *Utilization of Olší-Drahonín Uranium Deposit after Mine Closure*. 10th IMWA Congress, Mine Water and the Environment, 2008, pp 221-224, Karlovy Vary, Czech Republic, ed. Rapantova & Hrkal, ISBN 978-80-248-1767-5.

[10] RAPANTOVÁ, N., MICHÁLEK, B., GRMELA, A. & ZEMAN, J. *Hydrogeologické aspekty koncepčního modelu využití důlních vod zatopených hlubinných uranových dolů jako zdroje uranu*. Podzemná voda. 2007, XIII, Nr. 1, pp. 44-55. ISSN 1335-1052.

[11] RAPANTOVÁ, N., GRMELA, A., VOJTEK, D., HALÍŘ, J., MICHALEK, B. *Groundwater flow modelling applications in mining hydrogeology.* Mine Water and the Environment, 2007, XXVI, Nr.4, pp. 265-270, Springer-Verlag, ISSN 1616-1068. DOI: 10.1007/s10230-007-0017-1.

RESUMÉ

Uranové ložisko Olší se dobývalo v letech 1959 – 1989. Samovolné zatápění hlubinného dolu na ložisku Olší začalo v dubnu roku 1989 po ukončení jeho exploatace. Od roku 1996 probíhá čištění tzv. nadbilančních důlních vod vyváděných odvodňovací štolou z ložiska. Vyčištěné důlní vody se vypouští do povrchového toku. Klesající trend obsahu uranu v důlních vodách vyváděných odvodňovací štolou ze zatopeného ložiska Olší je zákonitý, protože ve svrchní části zvodně, tzv. mělký oběh důlních vod, se silně projevuje vyšší podíl infiltrovaných vod z atmosférických srážek, resp. infiltrace z povrchových vodotečí. Nejedná se tedy o reprezentativní trend obsahu uranu v celé zvodni akumulovaných vod v opuštěných důlních dílech.

Po ustálení hydrologického režimu se postupně vytváří v zatopeném hlubinném dole výrazná vertikální stratifikace vod, která je podmíněná zejména minimalizací jejich proudění po zániku hydraulického spádu vyvolaného původně aktivním odvodňováním dolu. Tyto zákonitosti jsou známé prakticky ze všech hlubinných dolů, rudných nebo uhelných. Rozsah mělkého oběhu závisí na hydrogeologických poměrech a způsobu rozfárání ložiska. Proudění vod v něm je vyvoláno řízeným vyváděním důlních vod (jedno zda čerpáním nebo gravitačně). Vody akumulované v hlubších částech bývalého dolu jsou téměř bez pohybu (tzv. kvazistagnující systémy) a koncentrace rozpuštěných látek je v nich výrazně vyšší, než ve vodách mělkého oběhu. Pro získání poznatků o tzv. kvazistagnujících vodách v hlubších částech bývalého dolu Olší byl v roce 2008 do ložiska navrtán hydrogeologický vrt. Výzkumný hydrogeologický vrt prošel komplexem nadložních hornin tvořených amfibolitem a biotitickými rulami a pod úrovní třetího patra bývalého dolu (cca 160 metrů pod úrovní terénu) již zachytil dříve dobývané žilné struktury. Je situován do prostoru mimo důlní díla, která slouží k aktivnímu odvodňování bývalého dolu. Je zaústěn až do důlního díla na 5. patře, tj. v hloubce 245 metrů pod úrovní terénu.

Na podkladě výzkumných prací (grantový projekt GAČR č. 105/06/0127) a hydrogeologického průzkumu, který potvrdil existenci předpokládané akumulace vod s vysokým obsahem uranu (obsah až 20 mg.l^{-1} v tzv. kvazistagnujících důlních vodách), byl realizován projekt na využití těchto vod. Technologický komplex pro získávání U z důlních vod uranového ložiska Olší byl vybudován se záměrem ověřit možnost průmyslového získávání U z kvazistagnujících vod akumulovaných v hlubších partiích zatopeného ložiska. Tento proces by zároveň měl zkrátit nutnou dobu čištění tzv. nadbilančních důlních vod vyváděných na povrch a vypouštěných do vodoteče. Realizované technické řešení umožňuje cirkulaci důlních vod v rámci ložiska Olší, kdy jsou vody čerpány z nižších horizontů a začerpávány zpět na hladinu a to při současném snižování obsahu uranu v těchto vodách. Uvedené technické řešení nemění současný stav vůči okolnímu přírodnímu prostředí, veškeré změny v cirkulaci důlních vod probíhají jen uvnitř zatopeného ložiska. Poloprovozní zkouška využití kvazistagnujících důlních vod s vysokými obsahy uranu bude poskytovat nezbytné podklady pro další teoretické práce (matematické modelování proudění a transportu látek v zatopeném dole) a zároveň bude sloužit k verifikaci teoretických poznatků.

Technologie stavby je projektována na čerpání 10,0 l·s^{-1} důlních vod z hydrogeologického vrtu (tj. z hloubky 245 m) po dobu 300 dní v roce. Stejné množství důlních vod bude začerpávacím vrtem zapouštěno zpět do ložiska. Začerpávací vrt je situován cca 600 metrů severně od čerpacího (hydrogeologického) vrtu, jeho hloubka je 27 metrů a je zaústěn do důlní chodby na 1. patře, které není zatopeno. Lze očekávat, že vlivem vyvolané cirkulace kvazistagnujících vod klesne obsah uranu v těchto vodách ze současné hodnoty 17,5 mg·l^{-1} na hodnoty nižší, v průměru kolem 15,0 mg·l^{-1}. Při těchto parametrech je teoretický výnos uranu 3888 kg za rok Pro srovnání, provozem čistící stanice důlních vod bylo v roce 2008 jako vedlejší produkt čištění získáno 1130 kg uranu.

Matematické modelování proudění v antropogenně narušeném masívu (např. hlubinnou těžební činností) patří k velmi problematickým úlohám. Důvodem je to, že v narušeném masívu vzniká systém proudění s preferenčními cestami (likvidovaná a nelikvidovaná důlní díla). Složité geologické podmínky ložiska Olší a geohydrodynamický systém s duální pórovitostí, navíc antropogenně narušený, klade jednoznačně vysoké požadavky na komplexnost řešení. Z tohoto důvodu bylo přijato rozhodnutí simulovat proudění a transport rozpuštěných látek na ložisku s využitím systému FEFLOW 5.2 . FEFLOW je interaktivní simulační systém na bázi numerické metody konečných prvků, který umožňuje simulaci hydrodynamických procesů, včetně transportu rozpuštěných látek a tepla, ve 2D nebo 3D systémech. Z hlediska modelových vstupů předpokládáme, že ložisko je dotováno pouze infiltrací ze srážek. Proto je zásadní stanovit správně vodní bilanci dílčího povodí , tj. rozdělení složek hydrologické bilance – přímého odtoku (povrchový odtok a odtok v pokryvných útvarech), evapotranspirace a efektivní infiltrace do modelované struktury. Pro tyto účely je využíván srážko-odtokový model HEC-HMS a bilanční model HELP (Hydrologic Evaluation Landfill Performance).

APPENDIX: Presentation “**Mine Waters of The Flooded Uranium Deposit in Olší**” - October 2009, Königstein, Germany