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USE OF WATER FLOODED URANIUM MINE AS ALTERNATIVE SOURCE OF ENERGY AND RAW MATERIALS*

Summary. Uranium mining was one of the most important industry branches in the former Czechoslovak Republic up to the mid 1990's. The Czechoslovak Republic was ranked the 7th in the world in production of uranium concentrate. Overall, there were 110 000 tons of uranium extracted during the period from 1945 to the mid 1990's. Currently, the underground mining of uranium is carried out only in the uranium mine Rožná. Exploitation of minerals is accompanied by the outflow of underground waters into mine excavations. The hydro geological regime of these deposits has become stable more than 10 years after the exploitation ended and the results gained by the hydro geological surveys have shown that the waters in flooded mines may present a significant secondary source of raw materials due to their volume and concentrations of dissolved substances (e.g. uranium). Mining areas are also an ideal retention environment for warm water as they are deep enough to ensure the water qualitative and quantitative stability. This paper deals with the mines in which the use of mined water, as a secondary source of uranium, of other minerals, or their energy or balneology use would be possible.

Key words: uranium mining, alternative source of energy, mine water

Introduction

Uranium mining was one of the most important industries in the former Czechoslovak Republic up to the mid 1990's. The amount of uranium output classified Czecho-

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slovakia for the 7th place in the world. Overall, 110 000 Mg of uranium was extracted (Fig. 1) in the period 1945-1990. At the beginning of the 1990's, the uranium output dropped significantly as the result of the uranium mines closing. At the moment, the extraction is continued only in the deposit Rožná, situated in Dolní Rožínka. Other deposits have been closed and are flooded.

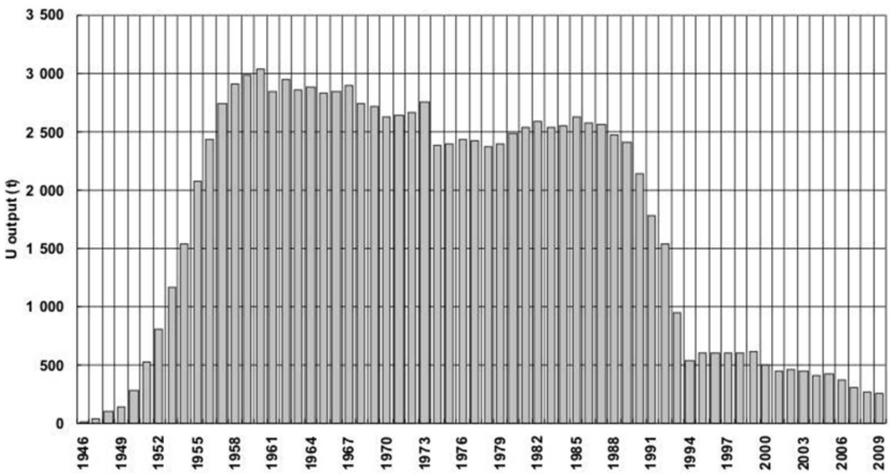

Fig. 1. Uranium production in Czechoslovakia in the period 1945-1990 (Michálek et al. 2010)
Rys. 1. Produkcja uranu w Czechosłowacji w latach 1945-1990 (Michálek i in. 2010)

The exploitation of the Rožná mine is currently conducted in uranium deposits situated at the depth of up to 1100 meters (the 24th floor). It is estimated that the exploitation would continue until 2015 and, then, it will be stopped because of economic conditions (no profit).

There were 164 uranium deposits discovered in the Czechoslovak territory. The extraction was carried out from 66 of them. The biggest Czechoslovak deposits were in Příbram, Jáchymov, Horní Slavkov, Zadní Chodov, and Rožná (Table 1).

This article discusses the problem with deposits of the endogenic origin. The deposits of the exogenic origin show different geological and hydro geological parameters. In consequence, the process of liquidation of the last mentioned deposits is carried out with the use of different methods.

The uranium production covered 42% of demands by the Czech nuclear power engineering in the Czech Republic in 2008. Uranium was produced from the 3 following sources (Michálek 2010):

- exploitation from Rožná deposit (84%),
- draining of the mine environment in Stráž pod Ralskem (10%),
- product of the mine water cleaning (6%).

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Table 1. Uranium deposits in the Czech Republic (MICHÁLEK 2010)
Tabela 1. Złoża uranu w Republice Czeskiej (MICHÁLEK 2010)

Deposit name	Extraction period		The amount of extracted uranium in Mg
	from	to	
Big deposit > 10 000 Mg U			
Příbram	1950	1991	50 200.8
Rožná	1957	present	18 965.8*
Medium deposit 1000 – 10 000 Mg U			
Jáchymov	1946	1964	7 950.0
Zadní Chodov	1952	1992	4 150.7
Vítkov	1961	1990	3 972.6
Olší	1959	1989	2 922.2
Horní Slavkov	1948	1962	2 668.3
Okrouhlá Radouň	1972	1990	1 339.5
Dyleň	1965	1991	1 100.5
Small deposit < 1000 Mg U			
Licoměřice -Březinka	1968	1982	466.3
Zálesí	1959	1968	405.3
Jasenice – Pucov	1963	1990	311.2
Předbořice	1965	1978	253.3
Chotěboř	1956	1977	148.8
Slavkovice-Petrovice	1964	1970	140.7
Potůčky – Princ Evžen	1946	1963	138.5
Kladská	1955	1958	115.9
Svatá Anna	1967	1972	115.8
Ústaleč	1958	1962	99.8
Damětice	1959	1963	83.9
Škrdlovice	1970	1975	76.3
Brzkov – Věžnice	1988	1990	65.3
Bernardov	1964	1965	55.5

*Deposit in service.
Places of the samples collection.

Materials and methods

The problems, connected with alternative applications of mine waters from the closed down and flooded uranium mines, were analysed within the Czech Republic Grant No. 105/09/0808 by the Technical University of Ostrava in cooperation with the State Company DIAMO. The mine waters could be used as an alternative source of uranium, of raw materials as well as of the geothermal energy. Additional advantage, apart from the gaining of raw materials, has been also a shorter time necessary for the mine waters cleaning, which has been funded, in the Czech Republic, from the state budget. A different way of the mine waters usage, applied in the deposit Horní Slavkov – Krásný Jez, is their use for fish farming (Figs. 2-5).

Fig. 2. The use of mine waters for fish farming (deposit Horní Slavkov – Krásný Jez) (Photo O. Babka 2010)
Rys. 2. Wykorzystanie wód kopalnianych do hodowli ryb (złoże Horní Slavkov – Krásný Jez) (Fot. O. Babka 2010)

After the deposit flooding, an intensive dissolution of uranium compounds takes place first. As a consequence, the concentration of uranium is increasing. Some differences in the uranium concentrations are also observed. The concentration of uranium in deeper layers is clearly higher than in upper layers. As a result of the above-mentioned differences, the cleaning up of mine waters from these upper layers is more profitable. However, the different use of mine waters – as the source of raw materials or energy,

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Fig. 3. The use of mine waters for fish farming (deposit Horní Slavkov – Krásný Jez) (Photo O. Babka 2010)
Rys. 3. Wykorzystanie wód kopalnianych do hodowli ryb (złoże Horní Slavkov – Krásný Jez) (Fot. O. Babka 2010)

Fig. 4. The use of mine waters for fish farming (deposit Horní Slavkov – Krásný Jez) (Photo O. Babka 2010)
Rys. 4. Wykorzystanie wód kopalnianych do hodowli ryb (złoże Horní Slavkov – Krásný Jez) (Fot. O. Babka 2010)

Fig. 5. The use of mine waters for fish farming (deposit Horní Slavkov – Krásný Jez) (Photo O. Babka 2010)
Rys. 5. Wykorzystanie wód kopalnianych do hodowli ryb (złoże Horní Slavkov – Krásný Jez) (Fot. O. Babka 2010)

prefers mine waters from deeper layers because of their higher temperatures and the quantity of dissolved substances.

Results

The samples of mine waters from the uranium deposits located in the Czech Republic (Fig. 6) were taken in August 2010. The results, gained from the deposits in Příbram, Rožná, Olší, and Jáchymov, were added to the data already possessed within the environmental monitoring system (U, heavy metals). In the case of analyses of small uranium deposits, the first measurements focused on the mine waters' quality. The objective of the conducted mine water analyses was the classification of their quality and quantity. The collected water samples were taken from the terrain surface, as well as from the underground pumped up waters (Table 1).

Basic parameters of mine waters were measured in situ (Eh, pH, temperature, and TDS). The analyses of heavy metals concentrations (As, Co, Pb, Zn, Ba, Cu, Sb, Ag, Al, Ni, and Sr) were conducted in accredited laboratories of the Technical University in Ostrava. Other analyses, investigating the content of U and Ra, were executed in accredited laboratories of DIAMO. The basic properties of mine waters, measured in situ, are presented on the following drawing.

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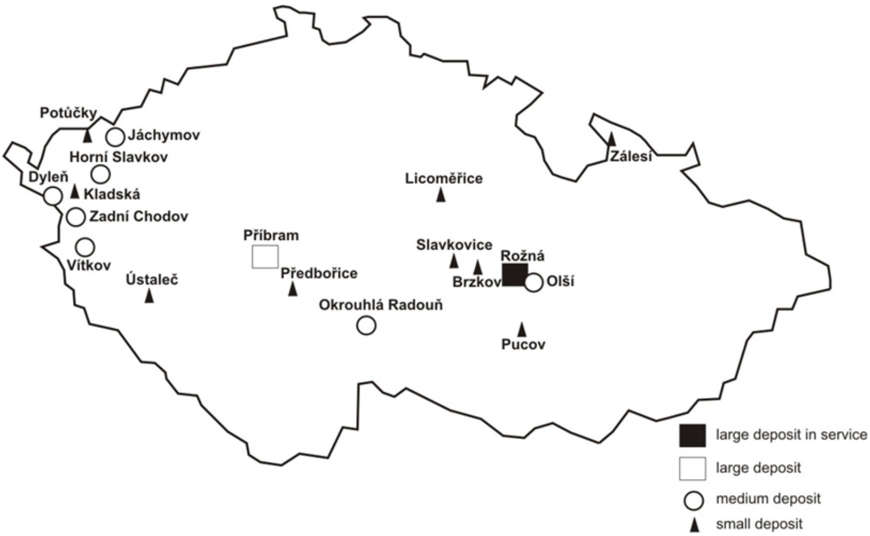

Fig. 6. Map of uranium deposits in the Czech Republic
Rys. 6. Mapa złóż uranu w Republice Czeskiej

Discussion

In the above-presented Figure 1, the only large deposits are Příbram and Rožná. The Příbram deposit was flooded in 2005 and Rozna has thus become the only exploited deposit in the Czech Republic.

In all the analysed samples (Fig. 7, Table 2), the mine waters from the deposit Příbram are characterised by the highest temperature, reaching 22.7°C. The relatively high temperature of these waters is the consequence of geological conditions (hot rocks). For that reason, as well as because of the huge quantity of these accumulated waters (about 20 million cu. m), they can be used as a geothermal energy source.

The higher concentration of TDS in samples of mine waters came from the Příbram deposit shafts Nos. 11 and 19. That was caused by the fact that the mine waters were taken from deeper deposit layers. After the deposit flooding, the concentrations of uranium and of other elements increased as the result of mineral dissolutions. During the pumping up from the deposits, the concentrations of substances in mine waters decrease because the waters mix up with surface and rain waters.

The analysis of the mine water from the deposit Příbram has shown the presence of a reductive environment (the negative Eh value). However, the deposit Rožná, probably because of the continued exploitation, has maintained its oxygenic conditions (the positive Eh value).

The medium size deposits have been flooded and liquidated. The deposit Jáchymov – used for balneology (the sources Svornost, Curie, Běhounek, C1, and Agricola), is the only exception.

Table 2. Basic parameters of mine waters measured in situ
Tabela 2. Podstawowe parametry wód kopalnianych zmierzone in situ

Deposit	Eh	TDS	pH	Deposit	Eh	TDS	pH
Příbram ČDV – 19	–92	2 680	7.25	H. Slavkov – Tagschacht	11	359	6.50
Příbram ČDV – 11	–103	2 530	7.22	H. Slavkov – Krásný Jez	12	350	6.97
Příbram Š – 55	–107	805	7.51	Okrouhlá Radouň	–64	1 178	6.93
Rožná	221	1 165	8.11	Dyleň	230	73	4.24
Bukov	217	665	8.08	Licoměřice	189	1 455	5.30
Jáchymov – Kozlí	92	195	7.18	Zálesí	233	242	7.45
Jáchymov – Eliáš	97	94	7.60	Pucov	–53	595	7.00
Abertamy	157	172	6.42	Předbořice	115	238	6.28
Zadní Chodov	–90	498	7.22	Slavkovice	108	351	7.40
Vítkov	–63	763	7.33	Potůčky – Princ Evžen	102	95	6.99
DS Olší	4	1 574	7.45	Potůčky – štoly	160	84	6.81
SS Olší	–39	1 710	7.13	Kladská	143	81	6.31
H. Slavkov – Barbora	–14	412	6.56	Ústaleč	–124	400	7.36
H. Slavkov – Pflug	8	211	7.26	Brzkov	88	40	7.53

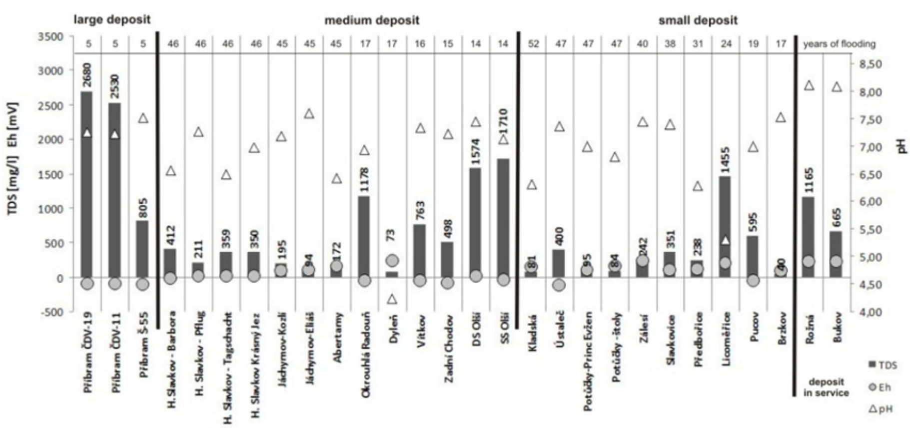

Fig. 7. Basic parameters of mine waters measured in situ
Rys. 7. Podstawowe parametry wód kopalnianych zmierzone in situ

The analyses of medium size uranium deposits have shown higher values of TDS, as well as the negative Eh value when the mine waters for the analyses were pumped up from shafts. It has been a characteristic feature of the reductive environment.

Mine water samples from other medium size deposits were taken from mine tunnels or ventilation shafts. Lower TDS values were affected by the hydro geological conditions – the presence of infiltrating surface waters. Their presence caused smaller contents of uranium and of other substances because of the mixing up. The Eh value indicates the oxygenic conditions. A very low pH value from the Dyleň deposit was caused by the presence of a peat bog in the area.

Conclusions

The results of the mine water samples analyses have shown that the contents of uranium, radium and other dissolved chemical substances did not reach values which would be dangerous for the environment. The chemistry of the mine waters was very similar to clean waters. As the result, the mine waters could be used, after some purification, for drinking. The only exception applies to the mine waters which could be used as an alternative uranium source (Olší).

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ZASTOSOWANIE URANOWYCH WÓD KOPALNIANYCH JAKO ALTERNATYWNEGO ŹRÓDŁA ENERGII I SUROWCÓW

Streszczenie. Wydobycie uranu było do połowy lat dziewięćdziesiątych ubiegłego stulecia jedną z najważniejszych gałęzi przemysłu ówczesnej Czechosłowacji. Czechosłowacja była klasyfikowana na siódmym miejscu na świecie, biorąc pod uwagę produkcję koncentratu uranowego. W okresie od 1945 do 1990 roku na terenie Czechosłowacji wydobyto łącznie 110 000 Mg uranu. Obecnie wydobycie podziemne prowadzone jest jedynie ze złoża Rožná położonego w Dolní Rožínce. Eksploatacji uranu towarzyszy wypływ wód podziemnych do wyrobisk górniczych. Ponad 10 lat po zakończeniu eksploatacji reżim hydrogeologiczny panujący w tych złożach stał się stabilny, a analizy wykazały, że wody kopalniane mogą stanowić źródło pozyskiwania surowców ze względu na dużą ilość i stężenia substancji rozpuszczonych (np. uran). Na terenach górniczych panują idealne warunki środowiskowe dla wód ciepłych, które znajdują się wystarczająco głęboko, aby zapewnić ich ilościową i jakościową stabilność. Duże stężenie substancji rozpuszczonych sprawia, że wody kopalniane mogą być dodatkowym źródłem uranu i innych substancji, jak również alternatywnym źródłem energii.

Słowa kluczowe: wydobycie uranu, alternatywne źródła energii, wody kopalniane

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