

THE RISE OF THE MINE WATER LEVEL IN THE AREA OF THE FORMER KOHINOOR II MINE AND THE INFLUENCE ON THE SURROUNDING AQUIFER SYSTEMS OF ABANDONED MINES IN THE CENTRAL PART OF THE NORTH BOHEMIAN BROWN COAL BASIN

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Abstract

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The aim of this article is to evaluate the process of terminating the mine water pumping after the liquidation of the Kohinoor II coal mine, situated in the central part of the North Bohemian Brown Coal Basin (NBB) and the subsequent resumption of pumping from the surface after the mine water rise in the area of the former mine to the desired level. We analyzed previously known data, particularly the amount of mine water pumped from the mine area and the surrounding abandoned mines in the past. Further the evaluation of known surrounding abandoned mines aquifer systems, accumulated in the coal seam (underground accumulation of water) and the evaluation of the effect of increasing the water level in the Kohinoor II mine, focusing on the enlargement of the central mine aquifers and the evaluation of the effects of changes in the way of pumping on the surrounding coal seam and its mining with continued safe brown coal mining at the nearby Bílina mine, that can be ensured for at least another 25 years.

mine liquidation, mine water pumping, abandoned mines aquifer, North Bohemian Brown Coal Basin

The article evaluates the ending the mining operations in the Kohinoor II mine, including the changes of pumping mine waters from it. Termination of pumping in the mine and the subsequent launch of pumping from the surface while maintaining a defined underground water level are evaluated. Furthermore the article contains an assessment of a new method of pumping mine waters, mainly with regard to their total amount and the amount possible to pump out also evaluation of changes in the hydrogeological regime of the mine systems is described, considering intense underground brown coal seam mining, not only in the area of the liquidated Kohinoor II mine, but

also in its wider surroundings, in central parts of the North Bohemian brown coal basin (hereafter NBB) located in the Czech Republic.

MATERIALS AND METHODS

The description of the condition and level of mine water accumulated in abandoned mines in the central part of NBB before the end of pumping at the KOHINOOR II mine

In the central part of NBB a relatively large number of studies were focused on the relationship between brown coal seam mining and mine waters accumulation. Provided mine waters were one of the biggest obstacles since the start of mining not

only in the NBB, this fact is clear and justified. These studies resulted in numerous outputs from areas, represented nowadays almost exclusively by former underground mines and also some strip mines, evaluating among others the water flow channels. The directions of water flow, beginning with the infiltration into coal seam outcrops below the Ore Mountains (Krušné hory Mts) especially, through individual hydraulically feasible paths between the mines, were credibly proved. Logically, the flow direction was towards the deeper parts of the coal seams, if the mining works or tectonic disturbances might allow it. The undistorted coal seam itself is viewed as an insulator, it became a collector due to the two above mentioned factors. Deep mines were due to the mining principles and the possibilities for safe and efficient mining mostly founded in areas bounded by tectonics, especially discontinuous. In the terms of safety and efficiency, eventually with the aim of merging them into larger mining companies, the mines were very often connected to each other.

The central area of the NBB, dealt with in this article, is bounded especially by the seam outcrops on the slopes of the Ore Mountains and the strip coal mines, active or with already ceased mining operations. These include the Československé armády (ČSA) mine, Obránců míru, Vršany – Šverma, Ležáky – Most and Bílina. Furthermore, we can consider the border line to pass through the former mines Barbora and Otakar near Oldřichov and the area between the mines, most of which are again natural outcrops of coal seam, the lesser part then are left over coal posts. In the area within

these limits, eleven partial more or less important abandoned mine aquifers in the coal seam were located at very different heights (eg the difference in elevation above the sea level of the Alexander and Nelson reservoirs, separated by a so called Inundation fault, is about 175 m). Following aquifer systems of abandoned mine workings have been taken into consideration:

Albrechtický in the ČSA mine foreland with changes of the water level at approx. 60m a.s.l. (measuring point is the pit VI, measured until present).

Jiřetinský – water level at 81m a.s.l. (measuring point is the drill hole HJI 325, today labelled as OM II, measured until present).

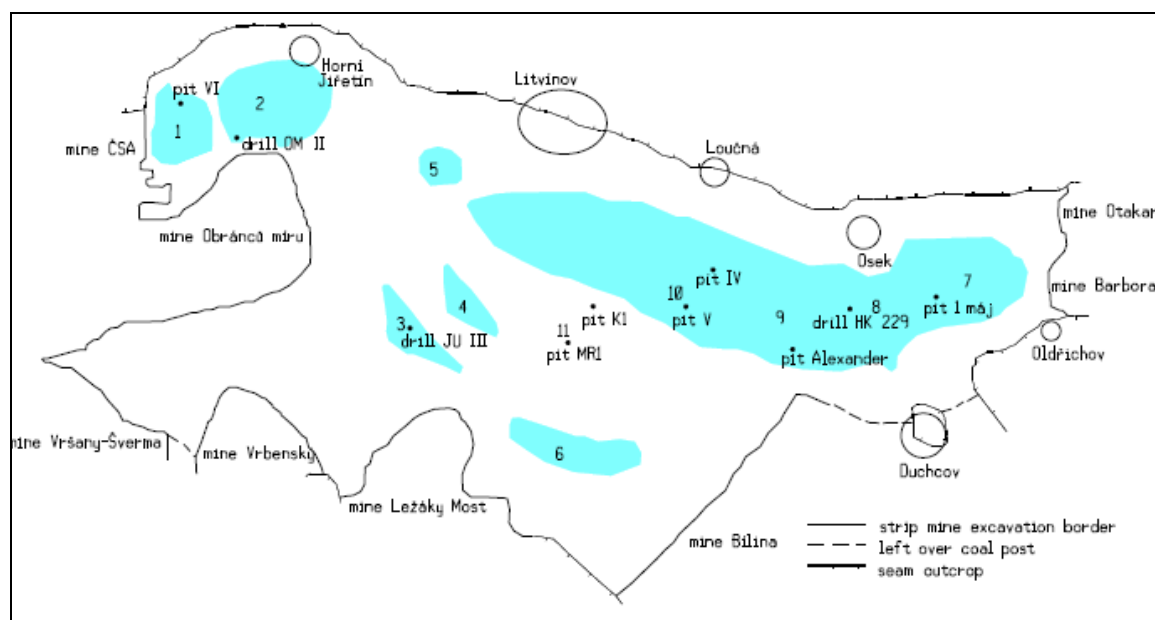
Centrumský – water level at 82m a.s.l. (measuring point is the drill hole KP 50, today labelled as Julius III, data from 15. 4. 2010)

Reservoir Viktoria – water level at 10m a.s.l. (not measured, the water level is assumed by the former studies).

Chudeřinský – water level at 20m a.s.l. (not measured, the water level is assumed by the former studies).

Venušský – water level at 57m a.s.l. (the water level is identical to the above sea level height of the bottom of the Bílina mine, where it emerges at the lower coal cut of the Venuše corridor; as the mine will progress into the deeper parts of the seam, the water level will drop).

Hájský – water level at 163m a.s.l. (measuring point is the pit 1. máj, measured until 21. 8. 2008).



1: Fig. 1: Scheme of the central part of NBB - situation of the abandoned mines aquifer systems in coal seams with an approximate area of filling and the situation of pumping and monitoring points – situation before 16. 6. 2008

Legend: the individual aquifer systems – 1 – Albrechtický, 2 – Jiřetinský, 3 – Centrumský, 4 – Viktoria, 5 – Chudeřinský, 6 – Venušský, 7 – Hájský, 8 – Nelson, 9 – Alexander, 10 – Kohinoor, 11 – Kohinoor II (before ceasing of pumping). Blue Area – an underground accumulation of mine water. Point – the place of mine water pumping or monitoring the water level height.

Nelson reservoir – water level at 163 m a.s.l. (measuring point is the drill hole HK 229, measured until present, data from 4. 2. 2010).

Alexander reservoir – water level at –12 m a.s.l. (measuring point is the pit Alexander 1, measured until February 2003).

Kohinoor I reservoir – the water level at –10 and –18 m a.s.l. (measuring points are the pits K 4 a K 5, measured until March respectively August of 2002).

Kohinoor II reservoir, no water level, pumping holds the water level below –90 m a.s.l. (until 16. 6. 2008), since 17. 5. 2010 the water level is held by surface pumping at the pit MR 1 at –20 m a.s.l.

The situation of these underground aquifer systems in abandoned mine workings is shown in Figure No. 1.

Localization of these abandoned mines aquifer systems was specified and confirmed by the [1] study carried out at the request of the following organizations: Palivový kombinát Ústí, state enterprise, as the administrator of the mining area of Lom II, Research Institute of brown coal, Inc., Most, evaluating the status in 2005, ie. considering the state of the active pumping of mine water in the Kohinoor II mine[1]. Also, the heights of mine water levels in each aquifer system were determined by this study. In some cases the water levels were updated by measurements, carried out by the organizations Palivový kombinát Ústí, state enterprise, Kohinoor centre, or our own measurements.

RESULTS

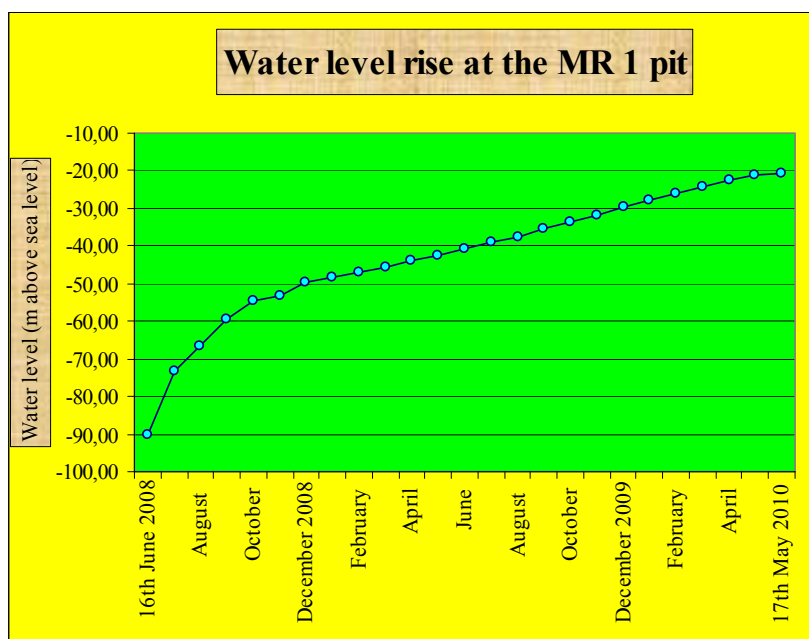
The evaluation of the mine water level rise at the Kohinoor II mine from the end of pumping in the mine to the start of

pumping from the surface by submersible pumps at the MR 1 pit

The underground mine water pumping at the Kohinoor II mine was terminated to be resumed from the surface with the installed submersible pumps. It was decided to start surface pumping when the mine water level would reach an elevation of –20 m a.s.l., corresponding to water level rise by about 70 m.

The reason for the continuation of pumping is the use of mine water as an alternative and complementary way of filling the Most lake, which is being created in the remains of the Most – Ležáky brown coal strip mine, and maintaining the mine water levels in the coal seam at a level that allows safe mining of the coal deposits in the nearby Bílina strip mine.

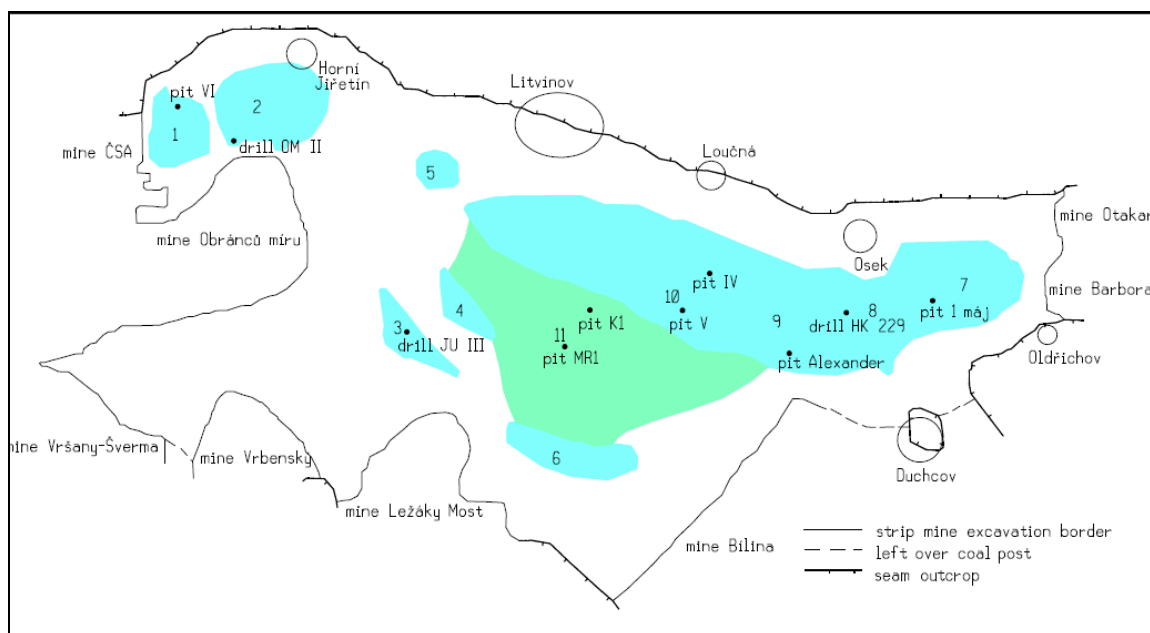
The pumping in the Kohinoor II mine was stopped, with regard to the other liquidation works carried out here, on the 16. 6. 2008. This was followed by the dismantling of the pumps, other remaining machinery and the electrical equipment and the completion of other necessary liquidation works [2]. The time needed to rise the water level from –90.04 m a.s.l., the foot-wall level of the excavation pit MR 1 and the deepest point of the Kohinoor II mine, to a level from which it is possible to perform an initial pumping test and then start the pumping regime, was the subject of many expert opinions. The estimates of the time it will take ranged from 5 months necessary to increase the water level to –20 m above sea level, to 5 years, needed to increase the water level to 60 m a.s.l. The fact is that the mine water level reached –20.5 m above sea level on 16. 5. 2010. The time it took to increase the mine water level to this level was about



2: Graph 1: The progression of the mine water level rise in the period between the end of pumping in the Kohinoor II mine and the start of pumping from the surface at the MR 1 pit

700 days, ie 23 months. It was closer to the more conservative expected scenario. The progression of the mine water level rise between the end of pumping in the Kohinoor II mine and the start of pumping from the surface at the MR 1 pit is shown in graph No. 1. On May the 17th, 2010 a pumping test at the MR 1 pit of the Kohinoor II mine started with the aim to find the most suitable pumping regime,

ie, determining the main parameters of pumping. These in particular are to determine the amount of water pumped, that will ensure the mine water level is maintained at the required level. This shows the number of pumps in operation, or a combination of individual or simultaneous operation. A view at the building of the former MR 1 pit is shown on Figure No. 3. Figure No. 4 shows a part of the water delivery



3: Fig. 2: Schematic representation in the area of aquifer systems in abandoned mines after changes in the central part of NBB caused by elevation of mine water levels in the area of Kohinoor II mine and its surroundings

Legend: the individual aquifer systems – 1 – Albrechtický, 2 – Jiřetínský, 3 – Centrumský, 4 – Viktoria, 5 – Chudeřínský, 6 – Venušský, 7 – Hájský, 8 – Nelson, 9 – Alexander, 10 – Kohinoor, 11 – Kohinoor II (after pumping at the mine stopped). Blue Area - an underground accumulation of mine water. Point – the place of mine water pumping or monitoring of the water level height.



4: Fig. 3: View of the MR 1 pit building



5: Fig. 4: The detail of the water delivery main in the MR 1 pit building

main, situated inside the building, on Figure No. 5 a detail of the monitoring pipe leading into the MR 1 pit is shown, passing through a steel reinforced concrete pentice.

The system for starting the pumps, including the monitoring of necessary data is located in the dispatch of the Palivový kombinát Ústí, state enterprise, Kohinoor Centre.



6: Fig. 5: The detail of the monitoring pipe

The rise of mine water level in the Kohinoor II mine to -20 m above sea level and the influence of its rising on the surrounding abandoned mines reservoirs

The changing of the pumping regime substantially changed the hydrogeological conditions in a major part of the considered area of NBB. This change means both an increase in the amount of water accumulated in the coal seam, as well as the merging of some described aquifer sub-systems into a single large underground Kohinoor aquifer. Meaning the connection off aquifers located in the deeper layers of coal seam, ie. reservoirs in the area of abandoned mines Kohinoor I, Kohinoor II and in part of the area of abandoned mines Vítězný Únor, Pluto and Alexander.

Other described aquifer systems are located in the coal seam, whose bottom is located above the water levels pumped at the MR 1 pit. Therefore they are not affected by rising water levels even when in the ground plan they are directly next to each other. In Figure No. 2 the changes in the hydrogeological conditions caused by overflow of the aquifer system Kohinoor II and its connection to the surrounding aquifers are illustrated.

In the past, the amount of mine water pumped from the Kohinoor II mine ranged from approximately 1.3 to 3 million m³ per year. The pumped out amount had an increasing tendency. The increasing amount was linked in particular to ceasing of pumping in the surrounding mines. In those the water levels were gradually increasing until they reached the so-called overflow level; when this level was reached, the mine waters from the surrounding mines began to flow toward the Kohinoor II mine and caused that a bigger amount had to be pumped. The amount of the mine water pumped annually during the last approximately



7: Fig. 6: The detail of the penetration of protective steel columns through steel reinforced concrete pentice

I: Annual amount of pumped mine water in $\text{m}^3 \cdot \text{year}^{-1}$ in the mines located in the central part of NBB

Year	Kohinoor 2	Centrum	Julius III	I. Máj	Pluto	Alexander	Total Sum.
1990	1 367 060	62 020	1 184 080	720 810	1 292 340	1 245 390	5 871 700
1991	1 357 310	18 650	836 100	659 530	1 795 510	1 166 970	5 834 070
1992	1 139 680	109 487	626 970	733 330	1 267 130	1 093 380	4 969 977
1993	1 035 967	548 038	966 984	704 340	942 564	1 133 350	5 331 243
1994	1 248 466	1 220 918	1 468 356	672 867	909 484	1 008 280	6 528 371
1995	1 463 404	1 369 717	1 449 284	706 694	739 508	874 247	6 602 854
1996	1 911 195	1 712 065	1 041 184	739 147	*354 538	958 091	6 716 220
1997	2 483 736	685 603	986 341	720 000	0	*315 700	5 191 380
1998	2 027 005	699 833	917 191	*63 306	0	0	3 707 335
1999	2 409 400	1 286 934	887 327	0	0	0	4 583 661
2000	2 794 867	1 684 490	828 688	0	0	0	5 308 045
2001	2 855 614	1 770 615	851 530	0	0	0	5 477 759
2002	2 951 759	1 011 500	*438 054	0	0	0	4 401 313
2003	2 944 230	1 908 400	0	0	0	0	4 852 630
2004	2 780 548	1 138 500	0	0	0	0	3 919 048
2005	2 888 679	1 513 320	0	0	0	0	4 401 999
2006	2 907 080	1 492 980	0	0	0	0	4 400 060
2007	2 856 040	1 631 300	0	0	0	0	4 487 340
2008	*1 326 900	1 703 000	0	0	0	0	1 779 900
2009		1 721 000	0	0	0	0	0
avg.**	2 144 681	1 069 335	960 161	635 558	1 043 011	974 426	4 718 245
sum.							95 614 905

* - pumping ended always during the given stated year

twenty years in the area is shown in Table No. 1. With respect to the maximum possible amount of considered mine water pumped the MR 1 pit is fitted with three submersible pumps embedded in protective columns at level approx. -25m above

sea level. Each of these pumps has a capacity of $3,6 \text{ m}^3 \cdot \text{min}^{-1}$, which gives the maximum pumping capacity of $3,6 \text{ m}^3 \cdot \text{min}^{-1}$, ie about $5 670 000 \text{ m}^3 \cdot \text{year}^{-1}$. Fig. No. 6 shows the penetration of submersible

pumps protective steel columns through steel reinforced concrete pentice.

DISCUSSION

The progress of test pumping showing the achieved results

On the May 16th, 2010 the pumping test at the MR 1 pit commenced. The main objective of the test operation was to determine the optimal pumping regime, where the mine water level is maintained at the desired level. In this paper a test operation in the period from May 16th to 31. 12. 2010 is evaluated.

In the monitored period the pumping regime was performed in the three basic options available, ie the system running all three pumps, two pumps and one pump, in the given order.

The pumping regime of all three pumps and two pumps in operation at the MR 1 pit has a similar progress. Within few hours the water level is lowered to the power-off level, which is set with regard to the height of the pump intake to -22.5 m above sea level. The time required to achieve the power-off level usually ranges between 4.5 to 5.5 hours of running the system with all pumps, and 7 to 7.5 hours for the system with two pumps running. The pumped out amount of water with the regime set to all three pumps in operation ranges from about 3 000 to 3 700 m³, with the regime set to two pumps in operation between approx. 3 000 to 3 350 m³. The amount of pumped out water is very similar for both regimes, the calculated per year the amount ranges from about 1 100 000 to 1 350 000 m³. Both chosen methods share a common characteristics in a relatively rapid lowering of the water level to the power-off level, while the level then relatively

quickly rises again to between -21 to -20 m above sea level. Both methods have been triggered once every 24 hours. If we compare the time it takes the water level to rise using both pumping methods, ie. 1.5 to 2.5 m in less than 24 hours with the time it took before the pumping commenced, when during the last approximately 18 months the average rise of the water level was in average 0.4 m per week, it becomes clear that the lowering of the water levels caused by pumping is not the same in the spill area of the abandoned mine aquifer system Kohinoor II. Clearly a depression cone is formed, which is then after the pumps are turned off in the time between 16.5 to 19.5 hours again levelled by the inflow of water into the area of the resulting basin. Also, the amount of pumped out mine water, converted to an annual amount, creates maximally 50% of the amount of mine water, pumped out here in the past.

After the pumping test with multiple pumps running, the pumping regime, which has always only one pump running started. In this regime during the evaluation period there was no occurrence, where the mine water level reached the power-off level and the pumping was suspended. Thus pumping continuously runs in this regime, with the fluctuation of the water level usually in the range from -20.5 to 21.5 m above sea level. The annual pumped out mine water amount, related to the continuous pumping with one pump is approximately 1 900 000 m³. This gives a presumption to short cyclical runs of the second pump to achieve roughly the same annual amount of pumped out mine water as was achieved in the past, ensuring the water levels are maintained at a specified level.

CONCLUSIONS

When deciding whether to continue the pumping of mine water in the liquidated mine or not, several possibilities were considered. First possibility being a complete termination of pumping, followed by thinking about options which would increase water levels to a several selected levels. A definitive stop of pumping and a stopping of all mining activities in the given area would ultimately result in a gradual rise of the mine water level, to a level at which the rising would stabilize, which is estimated at about 200 m a.s.l.. Due to the ongoing mining activities, however, this level was evaluated as not achievable in the near decades. As additional limiting states, the current and the planned lowest future level of exposed coal seam bottom at the Bílina mine, were considered, ie the levels of 60 m and -20 m a.s.l.. Given the assumption, that on both levels the amount of the pumped water would be almost the same, the option to maintain the water level at the lower level was chosen, with regard to ensuring the future safe excavation of the extractable coal seams at the Bílina mine. Obtaining the data published in this article allowed the evaluation of changes in the hydrological situation in the central part of the NBB and the proposal of the pumping regime at the MR 1 pit. The findings make it clear that continued safe brown coal mining at the nearby Bílina mine can be ensured for at least another 25 years, when the mine will approach the former Kohinoor II mine and will extract the seam, whose bottom will slowly drop to the minimum considered altitude of -20 m above sea level. It will also be possible to use the pumped out mine water for other purposes beneficial for the society.

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