Changes of hydrogeological conditions in the area of liquidated hard coal mines in the north-eastern part of Upper Silesia Coal Basin (southern Poland)

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ABSTRACT

Restructuring program that has been introduced since early 90's of the 20th century in the Polish hard coal mining, intensified the process of liquidating hard coal mines mainly in the northern part of the Upper Silesian Coal Basin. Eleven of hard coal, in which exploitation had been terminated in the years 1995-2000, were analysed in detail. Their total mining area was 252,7 km^2. Drainage of the workings in the closed hard coal mines is developed by means of one out of four methods: stationary, deep-well, mixed stationary – deep-well and gravitational. In flooded hard coal mines the rate of rising water table range from 0,04 to 1,28 m/d. The groundwater inflow into the analyzed area was reduced from 258,9 m^3/min (in 1988) to 112,2 m^3/min (in 2004), i.e. by ca. 43,3%. The amount of water collected in mine workings flooded till is 48,6 mill m^3 totally.

INTRODUCTION

Coal-bearing formation of the Upper Carboniferous in Upper Silesian Coal Basin (USCB) originated during the Variscan orogeny. The Variscian foredeep was then rebuilt during the Alpine orogeny. The formation of molasse coal-bearing deposits of USCB consists of clastic and phytogenic deposits. Paleogeographic conditions, lively tectonics, active sedimentation and differentiated rate of the collapse of a deposition area are the reasons for great diversity of both the type of deposits and sedimentation area. Total summaric thickness of coal-bearing deposits is estimated at 8500 m (Jureczka & Kotas 1995). Development of productive deposits in USCB is not even. In the discussed north-eastern part of USCB thicknesses range from several up to ca. 2500 m. In geological profile of productive Carboniferous of north-eastern part of USCB four lithostratigraphic units are distinguished: Paralic Series (PS, Namurian A), Upper Silesian Sandstone Series (UPSS, Namurian B and C), Mudstone Series (MS, Westphalian A and B), and Cracow Sandstone Series (CSS, Westphalian C and D) (Table 1).

In the area of north-eastern part of USCB the overburden of productive Carboniferous includes irregularly Triassic, Pleistocene and Holocene deposits (Table 1, Fig. 1). Predominant carbonate (limestone, dolomites) Triassic deposits are developed above all within the Bytom Trough. Their maximum thicknesses do not exceed 230-250 m. Pleistocene and Holocene deposits make a cover of differentiated thickness (from decimal parts of a metre up to ca. 50 m) on the older deposits. Sand and gravel (with clay insertions) deposits of water-glacial origin that fill up above all buried valleys of the Brynica, Czarna and Biała Przemsza rivers, have maximum thicknesses 20-50 m (Fig. 1).

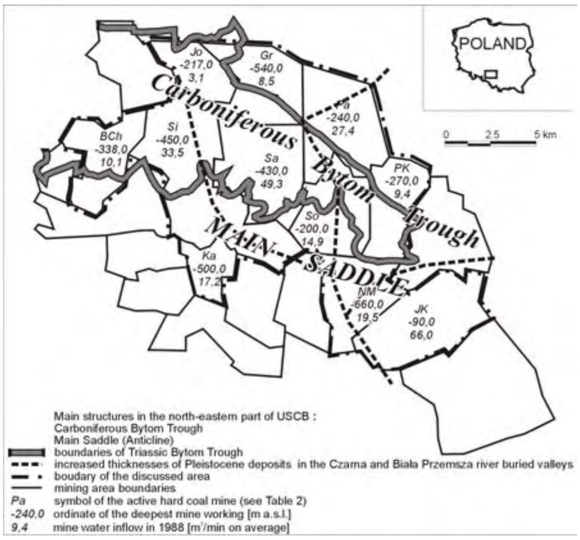

Figure 1: Location map of the active hard coal mine in the north-eastern part of USCB (state for 1988)

The discussed area is located in the zone of fault-block tectonics within the Carboniferous Bytom Trough, the dome fold of the Main Saddle (Anticline), and in its south-eastern part also on the southern slope of the Main Saddle (Fig. 1). In hydrogeological terms the discussed area is situated in hydrogeological north-eastern, open region of USCB. Because of elevated surface and occurring here hydraulic connections between aquifers of Neogene, Triassic and productive Carboniferous this area shall be regarded as the regional zone of recharging Carboniferous aquifers. The scheme of superposition of aquifers for the discussed north-eastern part of USCB is presented in Table 1.

Exploitation of hard coal deposits in the north-eastern part of USCB started in the second half of the 18th century. In the second half of the 80's of the 20th century there were over a dozen active mines in this area. Eleven of them, in which hard coal exploitation had been terminated in the years 1995-2000, were analysed in detail. Mining areas of these coal mines ranged from 8,7 to 33,9 km^2. Their total mining area was 252,7 km^2. Ordinates of the ground surface range from ca. +245,0 up to ca. 300,0 m.

Multiaquifer or aquifer formation	Isolating complex or level ^{d}-drainage of aquifers
Pleistocene and Holocene aquifer: sands and gravels of water-glacial origin, contemporary river deposits	^{d}-on a large area drained by workings of hard coal mines, locally in south-eastern part by surface sand mine
	residual clays, deluvial soil, boulder clays, varved clay
Triassic multiaquifer, Muschelkalk aquifer: cracked and karst-fissured dolomites, secondly limestones	^{d}-aquifer drained by lasting over 150 years Zn-Pb ore mining in the utmost western part of the area[1]
	marly deposits of Gogolin strata
Triassic multiaquifer, Roethian aquifer: cracked and karst-fissured limestones and dolomites	^{d}-drained by the mine workings of hard coal mines and well-intakes
	mudstones, claystones and marls of Lower Roethian and Upper Bunter Sandstone
Triassic multiaquifer, Middle and Lower Bunter Sandstone aquifer: sands, poorly diageneted sandstones	^{d}-drained by workings of hard coal mines
	mudstones and claystones of Lower Bunter Sandstone
Productive Carbonifreous aquifer: separate fracture-porous aquifers several to several dozen metres thick consisting of sandstones and conglomerates in CSS, MS, USSS and PS[2] profiles; sandstones and conglomerates are dominant in CSS and USSS geological profile	^{d}-aquifers drained by workings of hard coal mines
	claystones and mudstones several-several dozen metres thick in CSS, MS, USSS and PS profiles; complex of mudstones and claystones is dominant in MS and PS geological profile

Table 1. The scheme of superposition of aquifers in the north-eastern part of USCB

[1]- Kropka 2004;

[2]- CSS, MS, USSS, PS – lithostrtatigraphic units in Upper Carboniferous profile, accordingly Cracow Sandstone Series (Westphalian C and D), Mudstone Series (Westphalian A and B), Upper Silesian Sandstone Series (Namurian B and C) and Paralic Series (Namurian A)

SOME PROBLEMS CONNECTED WITH CLOSURE OF HARD COAL MINES

In the Polish hard coal mining active mines are treated as independent "mining intakes". Groundwaters coming from static and dynamic resources, drainaged by the net of mine workings within the active hard coal mine, flow into 2-4 chambers of main drainage, from which stationary pumping stations pump them out to the surface by means of pipelines. The above mentioned process excludes water flow between the underground mines. The depths of the lowest levels (sub-levels) in analysed mines ranged from 360 (-90,0 m ASL) to 910 m USL (-660 m ASL). In 1988 in 11 active hard coal mines there were as many as 23 shafts, through which mine waters flowing in the amount of 3,1 up to 66,0 m^3/min were pumped. Total inflow to the discussed mines according to the state in 1988 was 258,9 m^3/min (Table 2) (Rogoż & Posyłek 2000).

Restructuring program that has been introduced since early 90's of the 20th century intensified the process of liquidating hard coal mines mainly in the northern part of the USCB. Simultaneously with terminating exploitation of the deposit the process of liquidating the mine starts, which normally lasts for 1-3 years, and, depending on the mine drainage planned in future, comprises:

- liquidating technical infrastructure and chosen underground workings (mining galleries, shaft bottoms, shafts) and remaining at least two (for future drainage with stationary or mixed method) or one shaft (method of deep-well pumping),
- liquidating technical infrastructure (buildings, shaft hoist towers) on the surface.

Finishing the process of mine liquidation makes it possible to transfer the closed hard coal mine into the structure of the Central Department of Mine Drainage (CDMD). At present, according to the state on the day 31.12.2004, mining areas of active hard coal mines are situated mainly along western and southern order of the discussed area (Fig. 4). In order to estimate water threat in the hard coal mines neighboring with the flooded mine and to elaborate the prognosis of the successive stages of flooding a combined mines, it is necessary to recognize any connections to the mine workings of neighboring mines and to find the ordinate of the lowest connection. Exemplary hydraulic connections between the hard coal mines in northern part of USCB were presented in Figure 2. It is necessary to continue the drainage in closed mines until all hard coal mines belonging to the set of combined mines finish exploitation. In liquidated mines it is possible to flood only the lowest situated workings up to the height of overflow barrier of the lowest connection to the active hard coal mine (Adamczyk et al. 2000).

Drainage of the workings in the closed mines is determined by mining-geological conditions and can be developed by means of one out of four methods: stationary, deep-well, mixed stationary – deep-well and gravitational (Fig. 3).

Stationary drainage system requires at least two shafts to be preserved (most often with the total depth over 1000 m), pumping station of the main discharge on 2-4 levels, and gallery workings situated on several levels with a total length from several to over a dozen km. Such a system functions in the closed mines BCh, Si and JK (Table 2, Fig. 4). In these mines, provided that pumping system is maintained, the amount of drawdown and water flowing into the workings remain practically unchanged.

Table 2. Main data for the closed hard coal mines

Symbol of the hard coal mine	Mining area [km²]	Deepest mine working m USL (m ASL)	Mine water inflow (m^3/min)		Drainage systems in the closed hard coal mines (see the text); number of active mine shafts		Commence and terminate of the mining exploitation		Waters retention in the mine working, period of time // number of days in total	Water damming up level (m ASL) // the rate of the mine flooding process (m/d)	Water volume in the groundwater reservoirs (mill m^3)
			1988	2004							
		(W) 340 (-60)		0.3	Gr.				27.12.1999-11.09.2002 // 1019	-19.0 // 0.04	0.44
Jo[1]	12.6	(E) 500 (-217)	3.1	-	-	0	1912	30.10.2000	27.11.1999-01.05.2005 // 1982	+13.0[1] // 0.13[1]	1.8[1]
Gr[2]	33.9	800 (-540)	8.5	-	-	1	1901	31.12.1998	17.08.1999-01.05.2005 // 2084	+45.0[2] // 0.28[2]	7.9[2]
									28.11.1996-04.05.1998 // 522	+25.0 // 0.51	
									21.02.2001 - 26.06.2001 // 125	+30.0 // 0.04	
Pa	27.4	510 (-240)	27.4	12.3	D-w.	1	1885	30.06.1995	647	0.42 av.	5.3
BCh	14.4	630 (-338)	10.1	13.4[4]	St.	2	1822	31.12.1995	stationary drainage system	-327.0[3]	0.5[3]
Si	31.5	780 (-450)	33.5	10.6	St.	2	1776	30.09.1999	22.01.2000-25.05.2000 // 124	-327.0[3] // 0.99	0.83[3]
									03.11.2000-01.11.2001 // 363	+35.0 // 1.28	
									01.09.2004-14.02.2005 // 166	+50.0 // 0.09	
Sa	29.1	700 (-430)	49.3	22.2	Mix.	2	1887	31.12.1995	529	0.91 av.	7.5
									10.01.2001-15.03.2001 // 64	-121.0 // 1.23	
									20.10.2004 - 07.03.2005 // 138	-95.0 // 0.19	
So	20.5	450 (-200)	14.9	6.8	D-w.	1	1888	31.12.1997	202	0.52 av.	5.0
PK	17.4	550 (-270)	9.4	5.5	D-w.	1	1908	31.12.1998	21.09.1999-10.03.2002 // 536	-200.0 // 0.13	5.4
Ka	8.7	780 (-500)	17.2	5.4	D-w.	1	1823	01.07.1999	01.01.2000-02.10.2001 // 640	-200.0 // 0.47	7.2
NM	26.3	910 (-660)	19.5	9.5	D-w.	1	1810	01.07.1999	15.04.2000-16.09.2003 // 1249	-170.0 // 0.39	5.8
JK	30.9	360 (-90)	66.0	26.5	St.	2	1920	31.07.2000	stationary drainage system	+0,0	1.0

[1]- in the Jo mine two separate regions: western (W) and eastern (E); water retention in W region is finished and the water inflow into mine workings in the amount 0,3 m^3/min flow through a hydrogeological borehole to the neighboring active hard coal mine; region E in the course of retention (data according to the state of 01.05.2005);
[2]- in the course of retention (data according to the state of 01.05.2005); planned height of water damming up in mine workings +57,0 m is likely to be achieved in July 2005;
[3]- level workings had been flooded up to the ordinate of –327.0 m, which in case of Si mine, enabled the flow of some waters (ca. 9,0 m^3/min) from closed Si mine into BCh mine, causing increase of water inflow to the last mentioned[4];
[5]- sub-level mine working were flooded until the ordinate of +0,0 m.

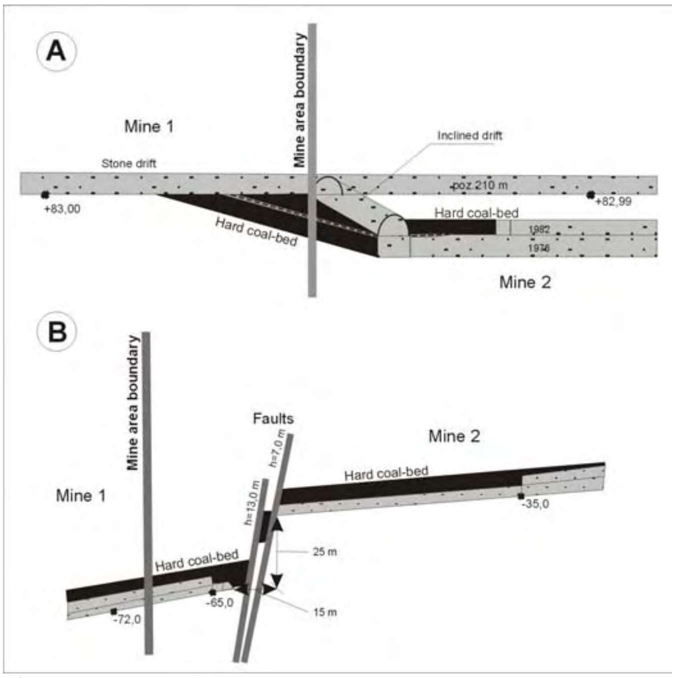

Figure 2: Exemplary of the direct (A) and indirect (B) hydraulic connections between the hard coal mines

Deep-well drainage system enables all stationary pumps to be shut off, the staff to be led out from the bottom of the mine, and all except one shafts to be closed. As a result of ceasing drainage in a closured mine water retention follows. In order to stop this process in mine workings and the whole mine formation it is necessary to turn on deep-well pumps suspended on a pumping pipeline located in properly prepared shafts. From this moment the pumps maintain dynamic water table within the earlier established ordinates. Such a system has been introduced to the closed mines Pa, So, PK, Ka and NM (Fig. 4).
In the Gr mine in the course of flooding mine working since above 1650 days. The planned height of water damming up in mine workings +57,0 m is likely to be achieved in July 2005 and then deep-well drainage system beginning.
Mixed, deep-stationary drainage system used only in the closed mine Sa also requires at least two shafts to be kept, more than 5600 m of the gallery workings and two pumping stations. Deep-well pump in a small shaft keeps water level in flooded workings within the established ordinates +50,0-+55,0 m, and then pumps water to the stationary pump of main discharge on the level of 210 i.e. +69,5 m ASL Stationary pump enables the waters to be pumped out to the surface.

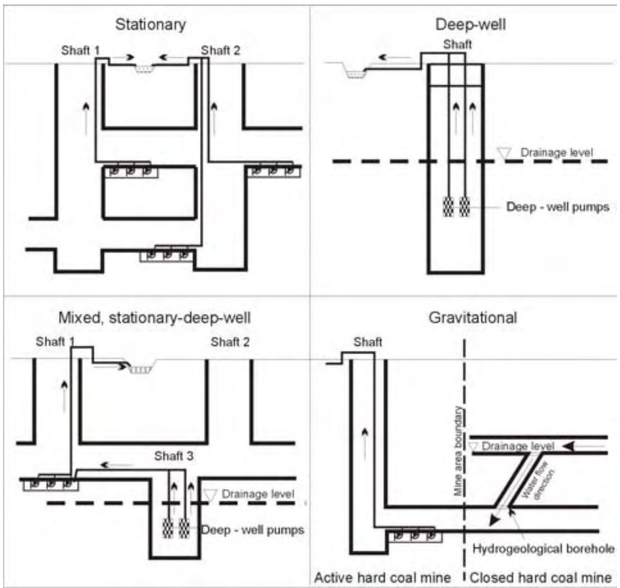

Figure 3: The drainage systems in the closed hard coal mines

Gravitational drainage is used only in the closed mine Jo. Intensive tectonics separates the mining area of this mine into two parts: western and eastern. Natural waters, after flooding the deepest sub-level mine workings in the coal-beds of 500 group (USSS, Namurian B and C) and creating an underground reservoir of ca 0,44 mill m^3 in its western part, are gravitationally led away to the neighboring active hard coal mine through a specially made for this purpose hydrogeological borehole, 600 mm in dimension and 129 m long to (Fig. 4).

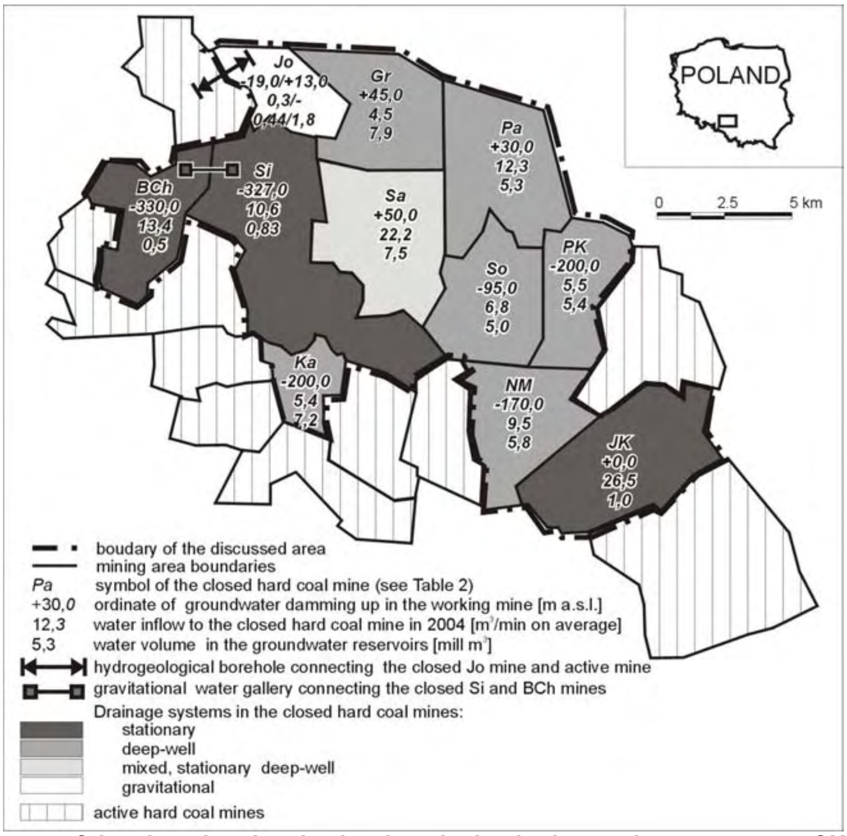

Figure 4: Location map of the closed and active hard coal mine in the north-eastern part of USCB (state for 2004)

THE RATE OF THE MINE FLOODING PROCESS. UNDERGROUND RESERVOIRS

Estimation of flooding time of the particular levels in the underground mine requires to define the water storage capacity of the workings and drained rock massif, and also forecasted water inflow into the underground workings. In flooded hard coal mines the rate of rising water table was differentiated. In the western part of the Jo mine water table in the course of flooding sub-level mine workings has been rising within the range of ordinates from –60,0 to –19,0 m with an average rate of 0,04 m/d. Decrease in drawdown by ca. 40,0 m did not cause reducing water inflow, which was maintained at 0,3 m^3/min. In flooded sub-level workings a reservoir emerged, with a volumne of ca. 0,44 mill m^3.

In Sa mine waters retention followed in 2 stages (Table. 2). In the course of flooding the workings within the ordinates – 430,0 to +35,0 m in the first stage that lasted 363 days, water table has been rising with the average rate of 1,28 m/d. Decrease in drawdown by ca. 465 m resulted in lowering average natural waters inflow from 46,0-49,0 to 22,2 m^3/min. Flooding the mine workings in the second stage within the ordinates +35,0 - +50,0 m was accompanied by much slower (0,09 m/d) rate of rising groundwater table. In mine workings of the Sa mine flooded in two stages an underground reservoir emerged, with estimated volume of ca. 7,5 mill m^3. In Pa, So, PK, Ka and NM closed mines that are being deep-well drained at the moment, dynamic groundwater table during water retention in mine workings and the whole Carboniferous formation has been rising at average rate from 0,04 to 1,23 m/d (Table 2). This process caused that drawdown lowered in this five mines within the ranges of 70 to 490 metres and water inflow was reduced by 44,7% i.e. from 88,4 to 39,5 m^3/min.

Present drawdown in the discussed 11 mines ranges from 160 to 560 m, which makes only ca. 60% (on average) of the initial value. This caused that groundwater inflow into the analyzed area was reduced from 258,9 to 112,2 m^3/min, i.e. by ca. 43,3%. It is estimated that amount of water collected in liquidated mines, in workings flooded till 01.05.2005, ranges from 0,4 to 7,9 mill m^3, which is 48,6 mill m^3 totally.

The discussed processes of flooding mine workings in closured hard coal mines did not take into account water flow between these mines. Only two closed mines are exceptional. Waters, in the amount of 0,3 m^3/min, from closed Jo mine are led away gravitationally through the hydrogeological borehole to the neighboring active hard coal mine. Some waters, ca. 9,0 m^3/min i.e. ca. 32% of the total water amount from closed Si mine, are gravitationally led away by means of water gallery 630 m long**,** made especially for this purpose, to the neighboring closed BCh mine. Additionally in 2004 the decision was made to change the ordinates of water damming up in two closed mines Sa and So. Thanks to it, waters, after having been dammed-up to higher ordinates, +50,0 and –95,0 m ASL accordingly, will be able to infiltrate to the liquidated mines nearby. Drainage systems in these mines are prepared for reception of accelerated amount of water.

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