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HYDROCHEMICAL CHANGES IN MINE WATER AFTER COMPLETING THE MINING AND FLOODING OF MINES IN THE PETŘVALD AREA IN THE CZECH PART OF THE UPPER SILESIAN BASIN

Summary. At phasing out mining activity in the western part of the Upper Silesian Basin – Petřvald Partial Basin, it was necessary to deal with pumping mine water and keeping water table in flooded mines. A conception for draining mine water away from the mines into the Zofie shaft was prepared. Development in concentrations of particular observed components is presented.

HYDROCHEMICZNE ZMIANY WÓD KOPALNIANYCH ZWIĄZANE Z ZATOPIENIEM KOPALŃ NIECKI PETRWAŁDZKIEJ W CZESKIEJ CZĘŚCI GZW

Streszczenie. W trakcie ograniczania i likwidacji działalności górniczej z zachodniej części GZW – tzw. niecce petrwałdzkiej (PPB) rejonu ostrawsko-karwińskiego (OKC) - należało rozwiązać problem utrzymania zwierciadła czerpanych wód podziemnych na poziomie, który nie pozwoli na niepożądany przepływ wód do sąsiednich fragmentów zagłębia. W tym celu wypracowano koncepcję doprowadzenia wód kopalnianych ze wszystkich kopalń PPB do szybu centralnego – szyb Žofie. W efekcie zatapiania zmianie uległy koncentracje niektórych składników pompowanych wód zbiorczych. Prezentowana praca przedstawia zróżnicowanie stężeń wybranych składników wód. Podano także mechanizm zmian zachodzących w czasie, porównano charakterystyczne trendy ze zmianami geochemicznymi, przebiegającymi w sąsiedniej niecce ostrawskiej, gdzie również nastąpiła likwidacja działalności górniczej.

1. Input Information

From the year 1995 pumping the mine water from particular mines in the Ostrava Partial Basin, henceforth referred to as OPB, (pumped quantity $Q_{max\ 1995} = 320\ l.s^{-1}$, i.e. including the proportion of operational water) was gradually finished and the complete abandonment of OPB mines took place in the year 1997 ($Q_{1997} \approx 250\ l.s^{-1}$, i.e. without operational water). In consequence, in the year 1997 the pumping of mine water in the Petřvald Partial Basin (PPB - $Q_{1997} \approx 57.6\ l.s^{-1}$ without operational water) was completed. With reference to the fact that coal exploitation has been since that year performed merely in the Karviná Partial Basin (henceforth referred to as KPB), it was necessary to protect this remaining part of the Ostrava-Karviná Coalfield from uncontrolled overflows of mine water from abandoned OPB and PPB (see fig. 1). A strategy for maintaining water levels in both the partial basins below the level of mine workings interconnecting the basins was adopted. For OPB the depth of about –385 m below sea level (i.e. about 620 m below ground) was determined. All the mines from the worked-out areas of mines have been pumped in the Jeremenko Pump Shaft in Ostrava (JPS). For PPB, the level of about –480 m below sea level (i.e. about 730 m below ground, 20 m below the lowest level of possible overflow of water into KPB) has been maintained by water pumping in the Zofie Pump Shaft by Orlová (ZPS). The determined water level was attained in the case of OPB in VIII/2001 and in PPB in X/2001. At present, average values of water pumping in these shafts to maintain the levels are as follows: JPS - $Q_{2004}= 133\ l.s^{-1}$; ZPS - $Q_{2004}= 37\ l.s^{-1}$. The overall area of flooded mine workings in OPB is about 73 km^2 and in the area of PPB is estimated at about 32 km^2.

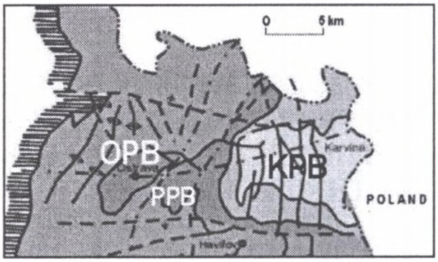

Fig. 1. The Ostrava-Karviná Coalfield and its parts:
OPB – the Ostrava Partial Basin
PPB – the Petřvald Partial Basin
KPB – the Karvina Partial Basin

Rys. 1. Ostrawsko-karwiński rejon GZW i jego części:
OPB – niecka ostrawska
PPB – niecka petrwałdzka
KPB – niecka karwińska

Up to now, inflows into JPS and ZPS are the ultimate inflow of prevailingly Quaternary water (water from Miocene horizon in a lesser degree – with regard to the minimisation of hydraulic gradient between aquifers in the overburden and the increased mine water level in flooded worked-out spaces) into the closed mines. The water from Carboniferous horizon is, in principle, almost totally eliminated by the level rise.

2. Mixed Mine Waters, Development and Changes in Their Chemism

Waters infiltrating the Carboniferous rock mass into mine workings (mine waters) are already, in the prevailing majority, mixed waters, or waters with changed chemism due to induced flowing, due to a decrease in the original pressure, degassing, due to the influence of stay in old mine workings, and others. The mixed mine waters were a result of various ratios of mixing waters from natural and artificial resources. However, information on the yield and composition of mixed waters was very important input information for forecasting the flooding of the Petřvald Partial Basin and a possible composition of used mine waters pumped in ZPS.

The monitoring of selected hydrogeochemical parameters and of control of mine water level regime in flooded abandoned workings followed from legal decisions on water using concerning the permission for pumped mine water disposal by discharging into the surface watercourse (Orlovská stružka stream→dosing tank→the Oder). This system of controlled disposal of mine waters in OPB and PPB has been operated minimally for 55 years; limiting parameters being determined for the boundary profile of the Oder River by the international agreement between the Czech Republic and the Poland, and in the year 2005 also for the profile of the Ostravice River at Muglinov. At present, limiting parameters are set as follows:

Table 1

Limiting values of surface stream load									
Monitored locality		TDS	sulphates SO_4^{2-}			chlorides Cl^-			Fe^{total}
Flow rate $m^3.s^{-1}$	*Ostravice*		*2-6*	*6-10*	*>10*	*2-6*	*6-10*	*>10*	
	Oder					*<10*	*10 - 16*	*>16*	
Ostravice River-Muglinov for OPB		1000 mg.l^{-1}	290	260	230	450	300	250	5 mg.l^{-1}
Oder River - Bohumín for OPB and also PPB		1000 mg.l^{-1}	200 mg.l^{-1}			350	300	250	5 mg.l^{-1}

The volume of empty mine workings situated below the altitude of -480 m below sea level was estimated at 3.6 million m^3. The capacity of retention space in the range of fluctuations in the minimum and the maximum level in the Zofie Pump Shaft (i.e. -480 to –476 m below sea level) amounts to about 40 000 m^3. This retention space ensures the filling for about 12.8 days.

Possible maximum inflows were calculated at 60 l.s^{-1}as a maximum; i.e. the overall annual amount discharged into the waterstream being 1.89 million m^3. The reality is as follows: 2002 = 1.204 million m^3; 2003 = 1.12 million m^3 and 2004 = 1.18 million m^3. For the expected permanent inflow of 60 l.s^{-1} the 75 l.s^{-1} capacity of pump was designed according to mining regulations. The current installed output of pumps in ZPS (150 $l.s^{-1}$) thus markedly exceeds the actual requirement for pumping to stabilise the mine water level in the worked-out areas.

It was supposed that a hazard to surface water could occur especially owing to the total dissolved solids in mine water (TDS), because in the first phases of pumping the mine waters from PPB (i.e. the first 3 to 4 years) TDS would be high and due to a substantial increase in the proportion of slightly mineralised surface water its value would be lowered relatively slowly (after almost total absence of Carboniferous water inflow and the minimised proportion of Miocene water). The content of chloride ion in the mine water pumped from ZPS is expected to be steady after sufficient "washing" the space of fluctuation in the maintained water level in the flooded area of PPB (after many tens of years of drying and saturating with crystallised salts). Other observed parameters from the point of view of water management are sulphate ions and ions of iron; from the point of view of water quality, primarily pH, Eh, conductivity, undissolved solids, As, Cd, Cr, Cu, Hg, Mn, Ni, Pb, Se, Zn, NES, PCB, PAH, benzo(a)pyrene, fluorantene, ^{226}Ra, U and temperature are systematically observed.

From the point of view of contamination load of surface streams, mines in PPB fell into the group of mines that contributed significantly to the pollution of water streams. Before mine closure, 19.1 % of water was pumped from the basal aquifer (so-called "detritus"= Dębowiec Member) and 29.2% from Badenian aquifers (Skawina Member); TDS of pumped mine waters amounting to 17.5 $g.l^{-1}$ (including 9.6 $g.l^{-1}$ of chlorides). At the produced quantity of mine waters of about 2.060 $mil.m^3$/year, 36 000 t of inorganic substances (including 19700 t of chlorides) were taken away into water streams annually.

At present, when ZPS is in operation (year 2005), TDS has the value of about 14.7 $g.l^{-1}$ (including 8.9 $g.l^{-1}$ of chlorides). At the produced amount of mine waters of about 1.2 million m^3/year, 17600 t of inorganic substances including 10700 t of chlorides and 24 t of sulphates are taken away into water streams annually.

The present state shows that the proportion of waters from Quaternary horizon amounts to about 26.7% and the remaining resources are Miocene aquifers (Skawina and Dębowiec Members).

However, a topical dominant problem in flooding the basin is not the contamination load of surface streams, but the problem of uncontrolled emissions of CH_4 through priority exit paths to the surface.

2.1. Hydrogeochemical Types of Mine Water Resources and the Quality of Water Pumped in ZPS

The hydrogeochemical composition of mine waters pumped to the surface is not a result of simple mixing their basic resources. This process is very complicated and any method used in sterile laboratory conditions, or methods of numerical modelling of chemical processes, calculations of hydrochemical balances, etc. cannot be applied to it. To the incomplete knowledge of mine water resources it is necessary to add further the alteration of mine water chemism due to diversiform hydrogeochemical reactions and oxidation processes during the stay of these waters in the mine atmosphere (days to years), alterations by the solving of salts contained in Carboniferous sediments, modifications by anthropogenic substances, including human and animal waste, and others.

Table 2

Proportion of mine water resources in the PPB [3]

Period / Resource		of mines in operation		after flooding the basin	
		$l.s^{-1}$	%	$l.s^{-1}$	%
①	Quaternary aquifers	26.7	45.8	26.7	71,4
②	Skawina Member	19.07	32.7	9.5	25,4
③	Dębowiec Member (detritus)	12.4	21.4	1.2	3,2
④	Carboniferous fissure water	0.05	0.1	0	0
Total		58.22	100	37.4	100

Table 3

Values of selected hydrogeochemical parameters [mg/l] of mine water resources in PPB (Archives of VŠB-TU Ostrava, IGI)

– for designation of resources see Tab. 2 and ⑤ waters from old workings

Resource		Ca^{2+}	Mg^{2+}	$Na^{+}+K^{+}$	Cl^{-}	SO_4^{2-}	HCO_3^{-}	TDS	pH
①	min	20	3	43	11	13	50	139	7.4
	max	163	34	202	468	320	187	1449	8.3
	Ø	78.1	14.1	98.9	141.0	148.8	114.2	586.7	7.5
②	min	570	96	15679	13812	12	101	23168	5.5
	max	2381	1179	47421	29686	59	672	48620	8.5
	Ø	1425.0	778.3	37363.8	23582.6	31.9	249.6	38932.3	7.0
③	min	153	52	5406	7338	2	10	12457	5
	max	2598	937	44665	31952	76	1008	62746	9
	Ø	777.1	427.8	20060.1	17599.0	28.8	313.1	28069.0	7.3
④	min	2411	899	18883	34590		109	66837	7.2
	max	3195	909	27196	37359		122	68833	7.6
	Ø	2803.0	904.4	23039.9	35974.3		115.3	67835.0	7.4
⑤	min	16	8	209	85	521	476	2415	7.5
	max	183	90	4187	5857	3452	2718	11739	8.5
	Ø	65.0	46.7	1651.1	1425.5	1275.1	1450.3	5926.5	7.7

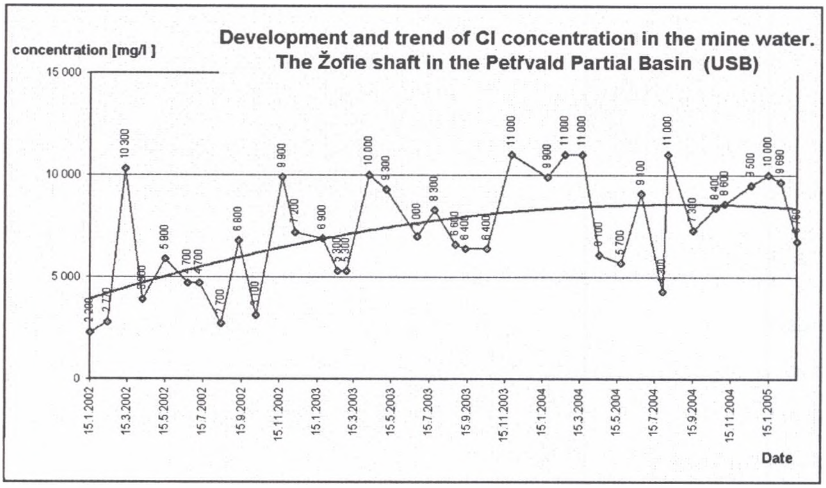

Fig.2. Development and trend of Cl concentration in the mine water. The Zofie shaft in the Petrvald Partial Basin
Rys.2. Zróżnicowanie stężenia Cl w wodach kopalnianych. Szyb Zofie w niecce petrwałdzkiej

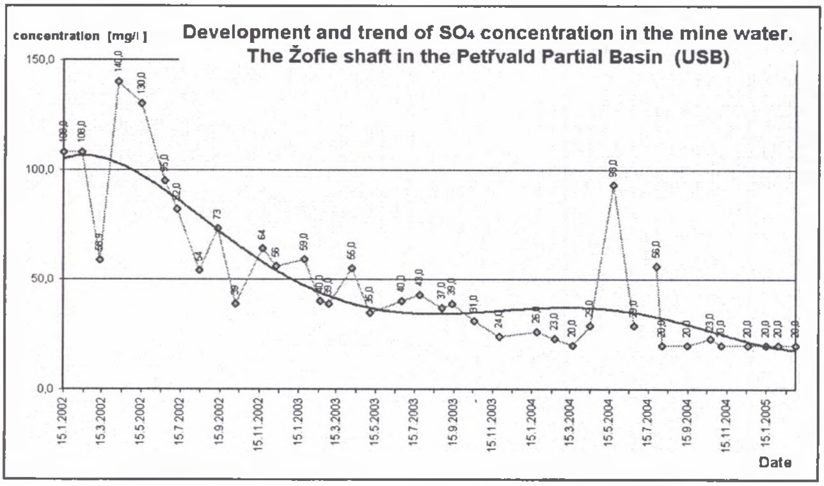

Fig.3. Development and trend of SO_4 concentration in the mine water.
The Zofie shaft in the Petrvald Partial Basin
Rys.3. Zróżnicowanie stężenia SO_4 w wodach kopalnianych. Szyb Zofie w niecce petrwałdzkiej

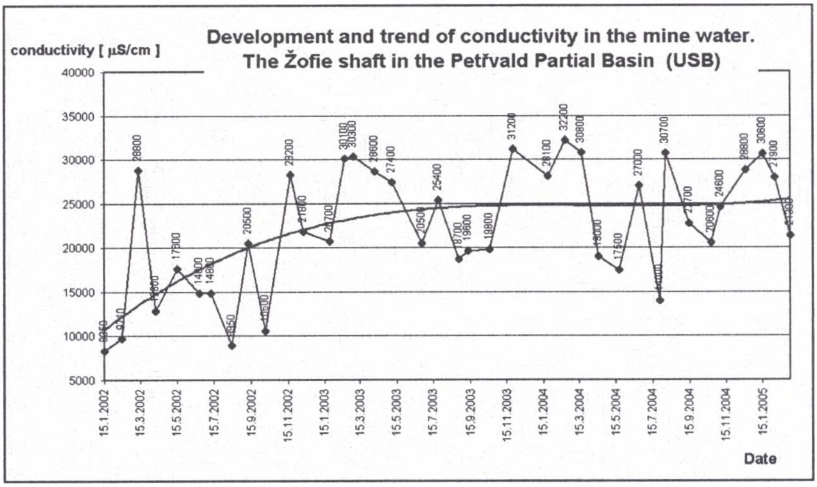

Fig.4. Development and trend of conductivity in the mine water. The Zofie shaft in the Petrvald Partial Basin
Rys.4. Zróżnicowanie przewodnictwa wód kopalnianych. Szyb Zofie w niecce petrwałdzkiej

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