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Mine waters in the Czech Republic – Current situation and trend development

Vladimír Slivka[a], Jiří Vidlář[a], Jan Thomas[b]*

[a]*Faculty of Mining and Geology, VŠB – Technical University of Ostrava, 17. listopadu 15, CZ-708 33 Ostrava-Poruba, Czech Republic (e-mail: vladimir.slivka@vsb.cz, phone: +420 597 321244, fax: 596 918 589)*
[b]*Institute of environmental engineering, VŠB Technical University of Ostrava, 17. listopadu 15, CZ-708 33 Ostrava-Poruba, Czech Republic (e-mail: jan.thomas@vsb.cz, phone: +420 597329391, fax: 596 918 589)*

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ABSTRACT

In the Czech Republic are mine waters well defined by Directives No. 254/2001 and No. 44/1988. Pumped mine waters from strip or underground mines are affected by increased volumes of iron cations, manganese cations, sulphates anions, acid carbonates and by acid pH. Excess limit volumes of dissolved solids are typical. The concentration of characterised pollution of mine waters does not allow direct discharge of these waters into the surface waters, not even their utilization without previous modification or treatment. Mine waters treatment technology on particular localities could be characterised as mechanical–chemical processes, including processes of solid matter sedimentation and further neutralization. This procedure ensures quality of treated waters for its discharge into the surface waters almost in all limited parameters of pollution. Exception is formed by excess limit concentration of dissolved solids (over 1,000 mg/l) and excess limit concentration of sulphates (over 300 mg/l). Chemical desulphuration processes represented by precipitation are advantageous methods with regards to realization possibilities and costs. Therefore, at the Faculty of Mining and Geology, VŠB-TU Ostrava, the fundamental attention was devoted to applications combining natural friendly calcic and aluminic ions that ensure reliable removal of sulphates. As the most suitable processes of current mine waters treatment appear to be tertiary processes, especially membrane technologies which are situated behind very effective pre-treatment removing solid particles. Membrane technologies could be used in procedure of final treatment as an advanced technology, which provide both demineralized water (permeate) and saline concentrate. Both products are for further commercial utilization.

Keywords: Mine waters; Desulphation; Open strip; Mine; Sulphates; Desalination; Membrane technologies

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1. Introduction

Mine waters belong to unique waters defined by the §40, Directive No. 254/2001 (Water Directive) and by §40, Directive No. 44/1988 (Mine Directive). These waters are all underground, surface and precipitation waters, that penetrate into strip or underground mine areas from overburden, subsoil, walls or simply like inflow of precipitation waters until theirs connection with others surface or underground waters. Mining organization have competence to use free of charge their mine waters for own demand. On the basis of water management authority permission an excess volumes of waters could be discharged into surface

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*Corresponding author

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or underground waters, respectively. Appropriate permissions, allowing drainage of mine waters into surface or underground waters, restrain according to administrative order No. 61/2001 pollution of discharged waters. However, pollutions not always match immission limits for surface waters in single indicators of contamination.

2. Characteristics of pollution of mine waters from brown coal mining

Mine waters pumped from open pits or underground mines are loaded with increased content of iron or more precisely also manganese ions, sulphates anions, hydrogen carbonates, acid pH, all above in consequence of iron sulphides oxidation (pyrite, marcasite), which are incorporated inside of coal matter.

The water is of poor quality because of those high levels of specific compound concentration, which could affect the surface water ecology if it is not treated prior disposal into the stream [1]. Transition of soluble mineral components from coal stratum into mine waters causes summarily above-limit contents of dissolved solids. Insoluble mineral components subsequently form dominant mechanical pollution, which is expressed by the suspended solids indicator. Oxidation of pyrite can be characterized by chemical diagrams according to Temple-Delchamps. However, it is always impossible to unambiguously evidence their stoicheiometric course:

$$2FeS_2 + 7O_2 + 2H_2O = 2FeSO_4 + 2H_2SO_4 \quad (1)$$

$$2FeSO_4 + \tfrac{1}{2}O_2 + H_2SO_4 = Fe_2(SO_4)_3 + H_2O \quad (2)$$

Overall reaction could have the following form:

$$4FeS_2 + 15O_2 + 2H_2O = 2Fe_2(SO_4)_3 + 2H_2SO_4 \quad (3)$$

In view of kinetics is important to know, that iron dissolution and oxidation process is limited by basic pyrite dissolving reaction (1) which is relatively slow. On the contrary partial reaction (2) is defined by speed characteristic that does not limit general process of iron dissolution and oxidation (3). Above-mentioned kinetic considerations indicate that air oxidations and water alone can not be practically in real time used for chemical degradation of pyritic sulphur in brown coal deposit, respectively in repository of untreated coal. Frequently cited biochemical reaction of pyrite decomposition are substantiated by desulphurisation effect of ferric sulphate – $Fe_2(SO_4)_3$ which is generated by biological oxidation of ferrous sulphate – $FeSO_4$ by means of bacterial culture of *Thiobacillus ferrooxidans*. Presence of free sulphuric acid in chemistry of pyrite dissolution is ascribing to oxidation effect of *Thiobacillus thiooxidans* bacterial culture on elemental sulphur that is an intermediate product of bio-catalyse. Mine water sulphates in the form of sulphuric acid are according to Visser et al. observed during the last step of bacterial oxidation when the pH is about 2–3 [2]. According to specific works catalytic influence of mentioned bacterial cultures on chemistry and decaying rate of iron disulphides is considered as crucial and usable also for pyrite biodegradation in repository of untreated brown coal, in stratum in-situ respectively [3]:

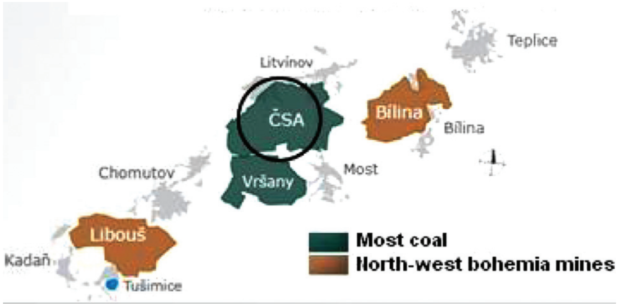

Fig. 1. Geographical position of mining localities of brown coal basin in North-West Bohemia.

$$FeS_2 + Fe_2(SO_4)_3 = 3FeSO_4 + 2S \quad (4)$$

$$2S + 3O_2 + 2H_2O = 2H_2SO_4 \quad (5)$$

$$12FeSO_4 + 8H_2SO_4 = 6Fe_2(SO_4)_3 + 2S + 8H_2O \quad (6)$$

Applicability of the above-mentioned chemical and biochemical reactions in relation to cleaning of water from mines could be summarised in partial conclusion indicating additive effect of air oxygen, bivalent iron and thion bacterias on total sulphate content of such waters.

3. Hydrogeological conditions and current state of mine waters treatment in northern part of the Czech brown coal basin

Czech brown coal basin in northern part of the Czech Republic is part of Tertiary basin systems of Podkrušnohorský shift. It is developed in territory among Prunéřov, Žatec, Most, Teplice and Ústí nad Labem (Fig. 1).

Hydrogeological conditions in particular regions of the northern Czech brown coal basin are considerably different. Underground waters belong to zone of active water exchange, as well as to deeper zone of slow water movement. Low mineralized water zones of quick

Fig. 2. High-volume strip mine ČSA with retention reservoir for mine waters transfer pump station.

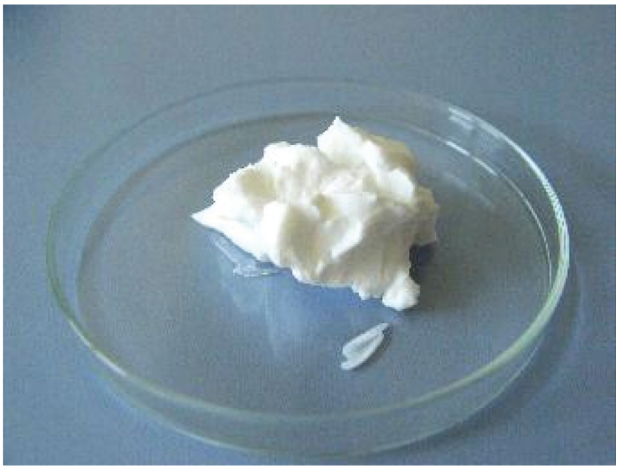

Fig. 3. Chemically precipitated sample of sulphatoaluminate-ettringite.

active exchange have Ca-hydrogen carbonate nature. In the stratum of brown coal are occurred waters of Ca-sulphate type with total mineralisation of up to several g.l^{-1}.

Due to mining activities communication and acceleration of both types of underground waters had happened. The most important aquifer system is formed by self brown coal stratum, which is corrupted by cut cracks and disruptions. From the mining point of view there are dangerous hardly drained irregular locations of Bílina and Žatec delta sands (quicksand), groundwater bodies of underlying gneiss near inundation disturbances in Krušné Hory, and slope and others Quaternary sediments at the piedmont of Krušné Hory, which forms permanent aquifer reservoir of shallow underground waters endowing deeper aquifers [4,5].

Quantities of pumped mine waters on quarried localities of north-west bohemia coal basin are considerable. For example pump station in large-scale open pit ČSA supplied in the year 2005 mine water treatment works by 1.78 millions of cubic meters of raw mine waters ($Q_h = 444$ m^3), pump station of Vršany pit had in the 2005 hourly capacity $Q_h = 330$ m^3 (at 2,979 h of annual operation). Dominant contamination of mine waters on mine localities of brown coal is formed beside to mechanical impurities, by suspended solids (range 100 mg/l), Fe^{2+} cations (range 100 mg/l), Fe^{3+} cations (range 100 mg/l), Mn^{2+} cations (units of mg/l), cations of Ca^{2+}, Mg^{2+} (range 100 mg/l), chlorides anions (range 10 mg/l). Mine waters pH is slightly even apparently acid. This derived from free sulphuric acid presence, which acts as donor of considerable concentration of sulphates (range 1,000 mg/l) as well. Dissoluble mineral forms are subsequently expressed by DS concentrations (units of g/l). In time scale is summary of mine waters pollution on existing localities variable, above all in relation to seasons.

Common overview on strip mine ČSA is given in Figure 2.

Above mentioned concentration of characteristic mine waters pollution do not allowed direct draining of mine waters into the surface waters not even their other utilization without previous treatment. Therefore mining companies operate treatment technologies on single mine waters treatment works, locally called mine waters works:

- MWW ČSA and JS,
- MWW Vršany,
- MWW Libouš,
- MWW Emerán,
- MWW Svatava.

Treated mine water is classified like surface water and therefore is amenable to immission standards of government order No. 229/2007. So-far troubled concentrations of below mentioned polluted matters are objects of exception that are provisionally licensed by local appropriate water management authority of public administration.

Existing technologies of mine waters treatment on separate MWW of mined localities could be simply characterised as mechanical–chemical procedures, used solid particles sedimentation process and processes of neutralization, oxidation and chemical precipitation of metals cations. Sedimentation is solved by front-end outside tanks, which ensured equalizing incoming raw mine waters as well. Sediment is periodically collected

Table 1
Mine waters pollution in inflow of MWW ČSA and JŠ

Parameter		r. 2005	r. 2006	r. 2007	1-7/2008
pH	min.	7.12	7.01	7.14	7.91
	max.	11.00	8.25	8.11	8.58
SS ($mg.l^{-1}$)	average	247.00	14.45	75.36	14.29
	max.	850.00	22.00	452.00	26.00
Fe ($mg.l^{-1}$)	average	0.89	1.13	1.00	0.30
	max.	3.35	4.09	4.27	0.59
Mn ($mg.l^{-1}$)	average	0.82	1.46	1.30	0.47
	max.	2.36	3.63	3.41	0.85

Note: in MWW volume of other pollution indicators is not monitored.

Table 2
Mine waters pollution in outflow of MWW ČSA and JŠ

Parameter		r. 2005	r. 2006	r. 2007	1-7/2008
pH	min	7.54	7.96	8.08	7.91
	max	9.29	8.87	8.61	8.63
SS ($mg.l^{-1}$)	average	7.08	12.30	18.77	10.43
	max	19.00	34.00	61.00	25.00
Fe ($mg.l^{-1}$)	average	0.31	0.11	0.09	0.18
	max	0.90	0.51	0.38	0.42
SO_4^{2-} ($mg.l^{-1}$)	average	771.82	722.60	793.82	730.29
	max	1126.00	889.0	1031.00	993.00
Mn ($mg.l^{-1}$)	average	0.33	0.18	0.32	0.40
	max	1.33	0.32	0.77	0.95
DS ($mg.l^{-1}$)	average	771.82	1387.50	1601.36	1502.00

and disposed e.g. on dumps. Neutralization of free sulphuric acid and chemical precipitation of cations are carried out by whitewash, Fe^{2+} oxidation by fine-bubble aeration, Mn^{2+} oxidation newly by potassium permanganate – potash. Originated treatment sludge is drained after flocculation and concentration by pressurized filtration on chamber filter press and furthermore efficiently disposed. Operation technologies ensure required quality of treated mine waters for their draining into the surface waters almost in all limiting indicators of pollution. How can be seen in Table 2 till this time exception stays in slightly above-limit concentration of dissolved solids (above 1 g/l) and highly above-limit concentration of sulphates SO_4^{2-}, which are limited for direct draining into surface waters by concentration of 300 mg/l.

In Tables 1 and 2 are mentioned for instance values of mine waters pollution parameters monitored over the last years in inflow and outflow from MWW ČSA a JŠ.

Treated mine waters from high-volume strip mine ČSA and JŠ are discharged into Bílina water object in fluvial kilometer – 56.0, in the amount of 2.5–2.9 mil. m^3 per year.

4. Characteristic of mine waters pollution from ores post-mining localities

After ores deposit mining activities, which has been finished in 1994 (except uranium mining), remain number of localities that burden surface water objects by spontaneously flow out or by purposefully pumped mine waters, which is mostly in next step treated. Water management on these localities is in administration of particular branch offices of state company DIAMO and GEAM – Dolní Rožínka.

Dominant pollution of these mine waters is formed by appropriate heavy metals, sulphates and volumes of dissolved solids, often when the pH is in acid spectrum. Elements like Cu^{2+} or Mn^{2+} which are concentrated in ore mine waters consequently contribute to stream pollution [6]. Condition and trend analysis of pollution of the Czech mine waters accomplished at VŠB-TU Ostrava, HGF [7] enables to specify localities, whose mine waters after treatment in MWW (neutralization technology) not even meet legal limits and in fact of significant quantity of these pumped waters excessively burden by pollution surface waters. The largest and so far not operationally

Table 3
Quality of mine waters in inflow of MWW Kutná Hora-Kaňk, 2007

		As	Fe	Mn	Zn	SO_4^{2-}	DS-105	SS-105
Parameter	pH	$mg.l^{-1}$						
I.Q/2007	3.3	83.7	4 100.0	95.1	679.0	11 080.0	19 740.0	102.0
II.Q/2007	3.5	82.1	4 112.0	91.3	641.0	10 717.0	19 250.0	145.0
III.Q/2007	3.4	82.2	3 994.0	88.6	575.0	10 505.0	18 500.0	169.0
IV.Q/2007	3.5	78.1	3 928.0	82.1	594.0	10 350.0	18 567.0	116.0
Ø 2007	3.4	81.6	4 025.0	89.2	622.0	10 660.0	19 000.0	138.0

solved problem of mine waters treatment process after mining of complex ores are excessive concentration of sulphates and dissolved solids. That could be illustrated on the chosen example from Kutna Hora – Kaňk location.

4.1. Mine waters treatment works (MWW) Kutná Hora – Kaňk

Silver ore mining proceeds already from the 13th century, modern history is dated from 1958 to 1991. Mine is slowly flooded from that year. Water level reached overflow dimension in September 2001. In consequence mine waters are pumped (from depth 110 m) from Turkaňk pit (overall pit depth is 550 m) and conducted on MWW. Everything is carried out on the grounds that are under the control of DIAMO – uranium deposit management Příbram. Quality of mine waters in 2007 on the locality Kutná Hora–Kaňk is shown in Table 3. Treatment technologies consist of common neutralisation and oxidation processes (Table 3).

In outflow from MWW are above pollution concentration still formed by 4,500–5,500 mg/l of dissolved solids and by 2,500–3,500 mg/l of SO_4^{2-} ions, when the average operation of MWW is 3.8 l/s. Outflow from MWW is led into Šífovka water object.

Sulphate removing process has been at VŠB-TU Ostrava, workplace HGF, one of the preferred courses of applied research in last 10 years.

5. Fundamental possibilities of mine waters desulphation

At the beginning, as potential possibilities of sulphates removal processes from mine waters was discussed:

- physical–chemical (membranous process, sorption, ion exchanging, flotofloculation, etc.),
- chemical (chemical precipitation),
- biological (desulphation bacteria influence).

Discussion was ended by laboratory research project, which was orientated on sulphate removing with application of chosen desulphation bacteria and on further methods of chemical precipitation. In those steps membrane methods was understood like economically too expensive.

5.1. Biological desulphation processes

Within favourable terms desulphation bacteria are able to reduce sulphates to insoluble sulphides which can be removed mechanically from waste waters [8]. For the given purposes of desulphation the following pure bacterial cultures were laboratory tested: *Desulfovibrio desulfuricans, Desulfovibrio vulgaris*.

Tested mine waters were from high-volume strip mine ČSA Most, volumes of sulphates were up to 2,600 mg/l. From the desulphation bio-tests results followed that application of chosen bacterial cultures requires special organic substrate dosage, optimum water temperature maintenance (about 35°C) and long reaction time, in order of hundreds hours. After 100 h of sulphates removal by activity of mentioned bacterial cultures the most achieved efficiency was about 25%. Moreover additional organic substrate negatively increases BOD indicator. From the purely research point of view study of adapted desuphation bacterial cultures can be recommended. Development of adaptable bacterias required transformation of genetic properties of cell to plasmides, which can be according to opinion of biotechnology researchers achieved with action of extreme saline sulphate waters for several periods of years.

5.2. Chemical precipitation of sulphates and its possibilities for mine waters applications

With regard to possibilities of practical application of potential technology as well as to economy of water desulphating treatment the process based on chemical precipitation of sulphates was preferred. Fundamental part of chemical precipitation study of sulphates were reactions of these sulphates anions with cations of metals forming together with sulphates low soluble and ecologically acceptable compounds [8,9].

5.2.1. Desulphation procedure with Ca^{2+} and Ba^{2+} ions

Calcium ions Ca^{2+} precipitate sulphates into forms of hydrated calcium sulphate. Solubility of $CaSO_4$ is about 2,000–2,500 mg/l and thus residual concentration of sulphates at equilibrium state oscillates about 1,500 mg/l, which means possibility of only partial desulphation with present donation of about 800–1,000 mg/l of Ca^{2+} ions.

Therefore considerable attention was dedicated to sulphates precipitation testing by Ba^{2+} ions. Process that is regulated by the following Eq. (7):

$$Ba^{2+} + SO_4^{2-} = BaSO_4(s), \tag{7}$$

is known from analytical chemistry as method for gravimetric analysis of sulphates. Product of solubility of reaction product-$BaSO_4$ is $Ks = 1.35 \cdot 10^{-10}$, the solubility is approximately 1.7 mg $BaSO_4$ in 1 dm^3 water, about 1 mg $SO_4{}^{2-}$ ions in 1 dm^3 water. As a donor of precipitating Ba^{2+} ions were in laboratory applied accessible salts: barium chloride, barium hydroxide, barium sulphide, barium carbonate.

Achieved results of desulphation showed high technological efficiency of sulphate precipitation, logically depended always on actual concentration of available Ba^{2+} ions. Disadvantage of wider method application is connected with unfavourable ecological effects of superfluous content of Ba^{2+} ions together with relatively high prices of barium compounds in desulphation waters.

5.2.2. Desulphation method based on combination of Ca^{2+} and Ba^{2+} ions

Method was developed at HGF, VŠB-TU Ostrava by financial support of Grant Agency of the Czech Republic and by straight research cooperation with company Mostecká uhelná, a.s.. By the help of this company were performed modelling and pilot plan experiments of mine waters desulphation in MWW conditions of high-volume mines ČSA and JŠ [9,10].

The principle of precipitation reaction consists in application of well-known chemical reaction, which takes place in hydration of milled cement calcium aluminates clinkers by water containing sulphates. As a result of these heterogeneous chemical reactions is forming of new, low-soluble mineral phases, sulphatoaluminates, knows as ettringite, which was like ''cement bacillus'' described e.g. already in the 1936 by Bannister. Example of sulphoaluminate-ettringite can be seen in Figure 3. Designed method of desulphation is based on direct interaction of calcium and aluminium ions with sulphates in water. Reaction proceeds in strong alkaline conditions [10–12].

From the theoretical point of view a conformation of probable course of the precipitation mechanisms is concerned:

$$\begin{aligned} &3SO_4^{2-} + 6Ca^{2+} + 2AlO_2^{-} + 4OH^{-} + 29H_2O \\ &= 3CaO \bullet Al_2O_3 \bullet 3CaSO_4 \bullet 31H_2O \end{aligned} \tag{8}$$

or

$$\begin{aligned} &3Na_2SO_4 + 6Ca(OH)_2 + AlCl_3 + 26H_2O \\ &= Ca_6Al_2(SO_4)_3(OH)_2 \bullet 26H_2O + 6NaCl \end{aligned} \tag{9}$$

Calcium hydroxide $Ca(OH)_2$ provides calcium and hydroxyl ions for reactions. In advantage, aluminium ions could be dosed like sodium aluminate $NaAlO_2$, which does not import further undesirable ions into treated waters.

Sulphates can be under control removed on required content, namely below 300 mg/l. Desulphation method designed at HGF, VŠB-TU Ostrava was well-proven in operation within investment venture of Energie, a.s. Kladno, connected with completion of mine waters treatment technology on bituminous locality VUD, a.s., Trutnov, mine Kateřina-Radvanice in the years 1999–2000 [13,14]. In those years was necessary to solve water treatment of waters that were lead off under control from spontaneously burning coal dump.

5.2.3. Desulphation sludge treatment

Developed technology of mine waters desulphation is patented [11,12]. Technology solves simultaneously also effective removal of all iron cations, manganese cations and of other metals, namely in its first stage at high alkalization of input waters by whitewash. This leads to chemical precipitation of monitored metals into the forms of their hydrated oxides. As a product of the first stage is alkalization sludge, which besides $CaSO_4 \cdot 2H_2O$ contains also solid phase of $Ca(OH)_2$ and hydroxides of metals.

Second stage of the technology produces alkalized treated water and desulphation sludge, containing

Table 4
Discharging profile: aquatic pit Jeremenko into Ostravice water object – mine water

Valid water management resolution:
No. 562/06 – OVP/1986.4462/04/Re
ŽPZ/1755/05/Kr

Defined parameters					Achieved real values						
Parameter	Value, m	$(\mathrm{l.s}^{-1})$ $(\mathrm{mg.l}^{-1})$ $(\mathrm{Bq.l}^{-1})$	Balancing value	$(\mathrm{m}^3.\mathrm{year}^{-1})$ $(\mathrm{t.year}^{-1})$ $(\mathrm{MBq.year}^{-1})$	Number of samples	Min.	Max.	Average, p	Number of exceeding	Balancing value	$(\mathrm{m}^3.\mathrm{year}^{-1})$ $(\mathrm{t.year}^{-1})$ $(\mathrm{MBq.year}^{-1})$
SO_4^{2-}	–	$\mathrm{mg.l}^{-1}$	–		12	536	688	645.417		3387.29	$\mathrm{t.year}^{-1}$
Cl^-	–	$\mathrm{mg.l}^{-1}$	–		12	4950	6510	5320.83		27924.89	$\mathrm{t.year}^{-1}$
DS	–	$\mathrm{mg.l}^{-1}$	–		12	10000	11000	10833.30		56855.71	$\mathrm{t.year}^{-1}$

mostly solid ettringitic component with possible admixture of hydrated calcium aluminates.

Third stage of the technology is connected with neutralization of treated waters by liquid CO_2 and produces neutralization sludge containing mainly calcium carbonates.

In technology may all of sludge products formed together general treatment sludge. Total production of the sludge is dependent especially on input sulphate content and could be multiples of sludge production on current MWW that has not have desulphation technological process. Therefore usability of treated sludge is till this time subject of unfinished research [15]. Partial conclusions provide usage possibilities of that sludge after his regeneration as a desulphation reaction reactant and also as additives of gypsum and sand mortar mixtures with superior technical parameters.

6. Mine waters pollution characteristics from bituminous coal mining

This chapter is devoted to mine waters from active mines situated in the Karviná and Frýdek-Místek districts of the OKR. Concern is focused on pumped waters from two ‘‘aquatic pits’’ (Jeremenko and Žofie) after termination of mining activities in the Ostrava-Petřvald part of coal field. Mine waters in post-mining localities of the OKR are under control of the state's company DIAMO.

Current state of mine waters treatment on those localities is characterized by pumping and after surface retention by control discharging into surface waters. In next section are for instance mentioned characteristics of dominant pollution in OKR mine waters. Waters are pumped after termination of mining activities in Ostrava part of the coal field through out aquatic pit Jeremenko.

6.1. Mine waters of the aquatic pit Jeremenko

Through pit pumping system are mine waters pumped on surface and discharged into surface water object – Ostravice in river kilometer 7.9. On the bases of the local water management authority resolution ŽPZ/3020/2007/, there are not defined any special limits for mine waters draining, except ensuring of fulfilling of given concentrations on border profile with Poland. That is realized by fulfilment of average concentrations of defined indicators on monitoring profile Ostravice-Muglinov.

Water type: neutral as far as slightly alkaline water, of essential sodium chloride type, dominantly native from capping of carboniferous rocks, quaternary aquifers and from surface rivers by direct filtration through bassets of carboniferous layers.

Discharged quantities (2007)	5,248,219 m^3/year

Before mixing of discharged waters with surfaces waters an analysis of chemical composition are provided in terms of resolution ŽPZ/3020/2007/, as follows:

SO_4^{2-}, Cl^-, DS, SS, Fe, conductivity, temperature	12× per annum,
Cd, Hg, Mn, Pb, Zn, NEM	4× per annum,
PAH (benzo-[a]-pyren, fluoranten)	1× per annum.

Results from chemical and physical analysis are for the year 2007 mentioned in Table 4.

6.2. OKR iodine-bromine salt waters

In the classical area of OKR are three balneological used localities:

Table 5
Summary of basic parameters of iodine-bromine salt waters from Ostrava localities

			Spa Darkov			Rehabilitative institute Karviná 8					
	NP 617 Šenov	Mine František	Vilemína	Nový Vrt	Helena	NP 735	NP 736	NP 737	NP 738	NP 745	Ostravice 1
	[mg/l]										
Ca	2,738.0	1,415.8	769.9	232.9	320.8	767.9	1,065.9	838.9	2,250.3	631.7	
Mg	743.0	508.2	341.3	103.0	155.6	309.0	467.2	339.0	826.5	275.5	
Na + K	16,874.2	12,168.6	9,869.9	4,677.5	6,223.9	10003.9	12054.0	10434.3	17373.0	9470.6	
NH_4		70.3	80.9	33.3	49.8	68.4	80.9	72.8	85.8	68.7	
Σ cat.	20,355.2	14,163.2	11,063.1	5,050.0	6,752.7	11152.6	13672.4	11690.5	20543.0	10451.8	
Cl^-	32,950.8	22,859.8	17,728.5	8,013.3	10,725.7	17817.1	21983.3	18703.6	33329.6	16664.8	12000–15000
Br^-	•	107.0	80.0	29.0	52.0	80.0	95.0	81.0	135.0	72.0	102–110
I^-	82.5	33.7	36.2	16.8	26.1	31.3	42.5	35.4	26.5	23.6	34–38
HCO_3^-	109.8	135.5	180.6	336.8	312.4	228.2	168.4	210.5	78.1	192.2	790–4200
Σ anion.	33,143.1	23,050.9	17,906.5	8,200.3	10,932.6	18014.3	22176.4	18897.0	33500.8	16828.1	
Sum	53,498.3	37,214.1	28,969.6	13,250.3	17,685.3	29166.9	35848.7	30587.4	54043.8	27279.9	
		Salt water reservoir									Temperat. 20°C

• bromides were determined probably together with iodides.

State medical spa Darkov, Rehabilitative institute Karviná 8 and Sanatoria Klimkovice.

All of these spa complexes are situated on regionally extensive geological structure of the main Dětmarovice and Bludovice scourds, where iodine-bromine aquifer in lower badenian collector was proved by tens of exploratory wells.

Mine Frantiček in Horní Suchá was the oldest exploited source of iodine-bromine waters in the locality of the main scourds. There was in operation partly swimming-pool iodine-bromine water-filled from so-called pit upper level and partly there was saltern in works, in which was produced so-called: Darkovská iodine salt.

In the following Table 5 is a summary of basic parameters of iodine-bromine salt waters from localities of the main scourds in the OKR mining district (analysis from the year 1990–database IGI, HGF, VŠB-TU Ostrava), complemented with new spa interested locality Ostravice.

From mentioned mine waters composition from OKR locality is evident that the only one effective technological model for treatment of those waters are modern membrane technologies with the most effective mechanical water pre-treatment as a front-end technological element. Obtained demineralised water and also salt concentrates (crystalline salt from evaporator) have to meet the requirements on commercial utilization. It comes to this that mine water treatment conception has to be solved like non-waste technology. Iodine-bromine salt waters can be among others used on research of possibilities of selective iodine and bromine concentration.

7. Conclusion

In compliance with Directive No. 254/2001 mining companies are obligated to concern about mine waters and to effective utilization of those waters as well. The biggest volumes of mine waters and matters pollution are pumped from our lignite localities, from some post-mining localities of complex ores and from localities of prior and current bituminous mining. As a final state a maximal mine waters utilization for mining companies own use can be considered. Or more precisely, those waters can be used consequently in tertiary (commercial) spheres including specific utilization for water supply purposes in case of developed critical situation about existing surface waters sources. Solving of some technological problems of current mine water works is presumption for approximation to mentioned state of mine waters utilization. On lignite coal and ore localities can be possibly thinking ahead about completion of current neutralization-oxidation processes by technological desulphation part of mine waters that contain above-limits of sulphates and with solving of sludge treatment according to described HGF, VŠB-TU Ostrava technology. However, extreme contents of dissolved solids, which are typical for local mines, can be probably solved by utilization of membrane processes.

Desalination of mine salt waters by membrane methods with subsequent utilization of both demineralised waters and salt concentrates could be characterised as an objective state of mine salt waters treatment. It shows very practical in relation to innovation of modern membrane processes (electrodialysis, reverse osmosis and their combination) proves these technologies on chosen localities at the level of pilot plant experiment.

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