Complicated water quality and stratification at the post-mining pit lake Medard near Sokolov, Czech Republic

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Abstract This article describes complicated stratification and water quality in the post-mining pit lake Medard, located in the north-west region of the Czech Republic. Flooding of the lake started in 2008 with water from mining sites, water basin of the lake and from river. We discovered a chemocline that disappeared after autumn circulation in 2009, but only in east part of the lake. Three months experimental filling of the lake with water from river at 2010 caused another chemocline all over the lake. Besides of the lake Medard, another post mining-pit Boží Požehnání is monitored.

Key Words post mining-pit lake, water quality, stratification, abandoned mine land, mine reclamation

Introduction

The number of abandoned open cast mines increases in the Europe in last decades. Heavily impacted landscape should be reclaimed to reduce damages on the landscape, nature and ecosystems caused by coal mining. Many of the former open-pits are flooded either by groundwater or with water from nearby water sources (Karakas et al. 2003). Many of lakes are located in Germany. The water in these lakes is usually more or less acid and thus is containing a high load of dissolved minerals (Boehrer et al. 2000). These lakes are usually located near by settlements and thus recreational utilization without healthy risks pay key role in designing and managing lakes.

Czech post-minig pit lakes have different geological subsoil. The groundwater have higher acidity, but final mixed water in lakes is more or less neutral. The abandoned open cast mines are usually and mainly flooded with water from near by rivers. It could lead to eutrophication with high numerous of cyanobacteria. For better understanding of the flooding procedures and for future flood modeling we need to observe processes in these lakes. In this study, we compare new lake Medard (Fig. 1) with old lake Bozi pozehnani (Fig. 2).

Post mining-pit lake Medard is situated in the North-west region of the Czech Republic. The mining history of the region started at the end of 17th century. At the very beginning mineworkers extracted minerals, later than the coal was collected and has been used as fuel. In the mid 19th century, there were 36 underground pits. Since the region was connected with railway during 70´s of 19th century, huge growth of the coal pits started. After political changes in East Europe in late 80´s of 20th century, many of pits were closed and new govern-

Figure 1 *View of the Medard open cast mine near Sokolov.*

Figure 2 *View of the BoziPozehnani open cast mine near Kynsperk nad Ohri.*

ment declare mining limits for all underground and open-pit mines. Therefore many reclamation projects started in the beginning of the 21st century in the Czech Republic.

The Medard lake was designed as a reclamation of two lignite open-pits: Medard and Libik. The open-pit Medard was established in 1920, open-pit Libik was established in 1872. The highest annual output of lignite was 7.883.000 t at Medard in 1983 and 3.571.000 t at Libik in 1982. Both open-pits were gradually merged between end of 80´s and beginning of 90´s of the 20th century. Mining activities has been stopped in March 2000. The area affected by mining activities was 1.183 ha. New reclamation project was introduced in June 2001. The bottom of the pit should be flooded with water and rest of the land impacted by coal mining should be reclaimed with typical reclamation activities e.g. with soil handling, land shaping, revegetation and reforestation.

Study sites and methods

Medard lake is located in the north-west part of the Czech Republic, in Karlovy Vary district, on the west edge of the town Sokolov (50°10' north, 12° 36' east). Designed parameters of the lake are: area: 493,44 ha, water volume: 119 850 768 m³, length: 4 000 m, width: 1 500 m, max depth: 50 m, altitude of water level: 400 m above see level. It's flooding started in July 2008 after the pump-

Table 1 *Average water quality data in Medard lake.*

		drainage in basin	mining corridor Josef	river Ohře	lake above chemocline	initial water in lake
pH		7.680	4.040	7.000	7.060	5.707
alkalinity	mmol/l	5.108	0.000	0.823	0.949	0.897
acidity	mmol/l	-	7.530	0.184	0.160	0.421
CHSK-Cr	mg/l	47.000	24.000	17.000	9.000	5.667
NH_4-N	mg/l	0.039	1.569	0.129	0.643	1.450
NO_3-N	mg/l	0.099	0.068	1.775	0.449	0.648
NO_2-N	mg/l	0.004	0.006	0.027	0.016	0.021
Norg.	mg/l	0.627	1.028	0.835	0.380	0.753
TN	mg/l	0.770	2.348	2.118	1.658	2.873
PO_4-P	mg/l	0.007	0.100	0.033	0.014	0.007
TP	mg/l	0.069	0.143	0.134	0.037	0.029
Na	mg/l	61.700	14.300	20.700	274.400	272.667
K	mg/l	9.500	4.700	3.400	11.300	12.233
Ca	mg/l	123.400	93.000	23.300	246.000	265.000
Mg	mg/l	102.700	21.500	6.600	86.100	102.100
Fe	mg/l	0.100	124.730	0.560	0.470	7.767
Mn	mg/l	0.120	3.290	0.110	1.780	3.280
Cl	mg/l	5.500	19.900	28.800	15.300	16.287
SO_4	mg/l	785.400	682.000	40.300	1507.400	1395.300
conductivity	µS/cm	1481.000	1177.000	289.000	2603.000	2563.000
susp. solids	mg/l	8.800	5.100	11.600	3.700	5.730
chlorophyll	µg/l	5.900	0.000	18.800	1.300	-

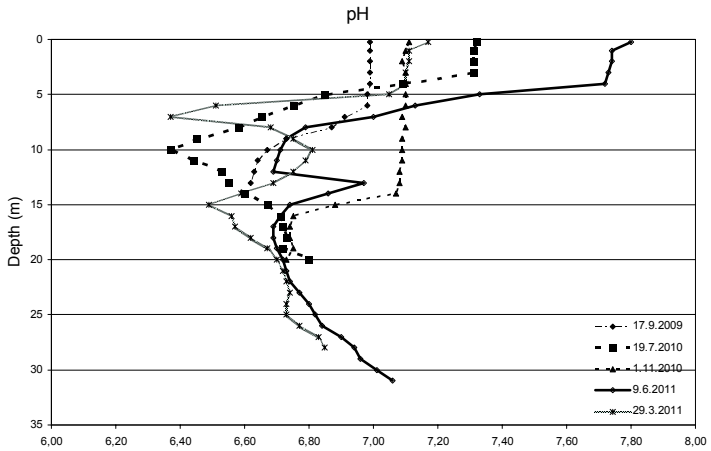

Figure 3 *pH change in Medard lake.*

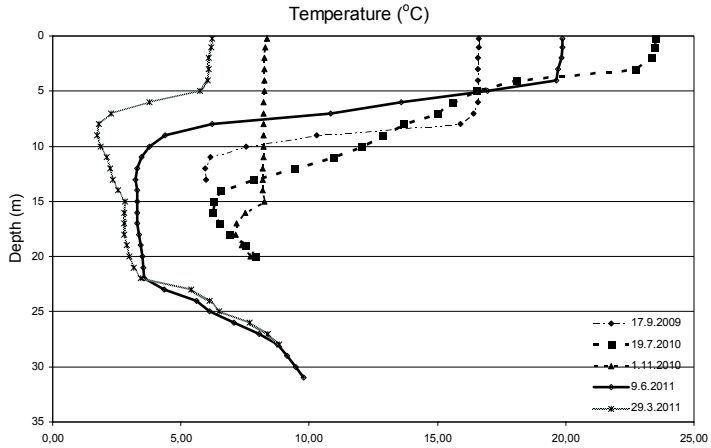

Figure 4 *Temperature change in Medard lake.*

ing of groundwater has been stopped in June 2008. At that time, there were 3 water ponds. Water quality was different in each pond, also metal concentration in water was different but corresponding with pH level. In the first half of the year 2009 the ponds merge together and regular monitoring of water quality has been started. Inflow of the lake covers groundwater, water from near by river Ohre and precipitations and outflow from water basin of the lake. Samples were taken from the water surface in east part of the lake in the beginning and water stratification was also monitored. Gradually the monitoring was enlarge to the center and west part of the lake and monitoring of zooplankton and basic chemical analysis of water has been started.

The Bozi Pozehnani lake is located in the northwest part of the Czech Republic, in Karlovy Vary district, near by the town Kynsperk nad Ohri (50° 7' north, 12° 31' east). The maximum depth of the lake is 23 m, length 430 m, width 377 m. The open cast mine was opened in 1880 and was closed in 1946. From the beginning there was high volume of groundwater inflow (5,5 m^3/min). Increasing water level endangered near by railway. Thus the pump station was operated till spring 2011. There is massive constant inflow of groundwater and water level is increasing. The bank with railway was reinforce with massive stone armouring.

Vertical profiles of temperature, pH, conductivity, dissolve oxygen, turbidity and chlorophyl concentration are taken at the deepest points in the west, centre and east part of the lake. We use multi-parameter probe YSI 6600 XL. The measurements are taken during daytime approximately once a month. Date are recorded at each 1 m depth.

Chemical parameters were analysed in laboratory with atomic absorption spectroscopy method (AAS). Cations and anions are analysed with the SpectrAA 640 – Varian analyser, ICP – OES iCAP 6000 – Thermo scientific analyser and flow injection analyser FIASTAR 5000 – FOSS.

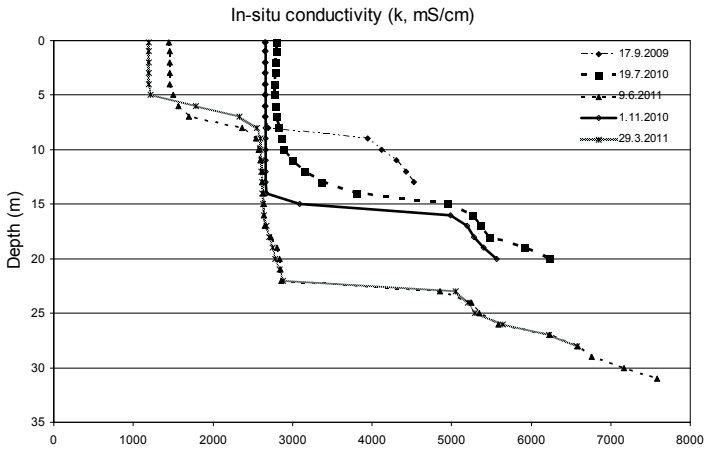

Figure 5 *Conductivity change in Medard lake.*

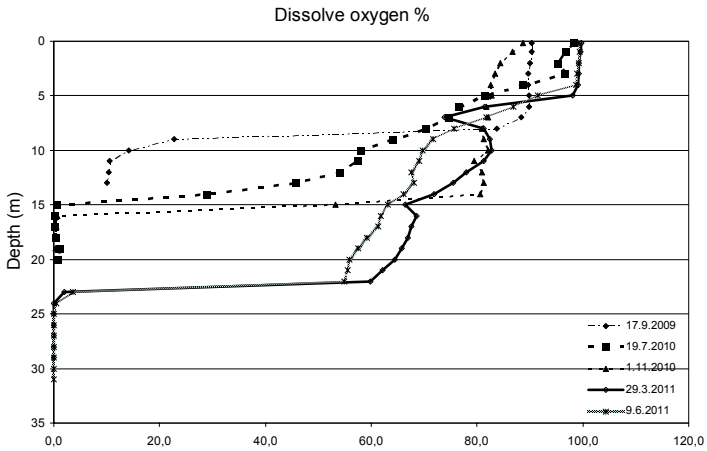

Figure 6 *DO change in Medard lake.*

Conclusions

In comparison with natural lakes, the Medard lake has very complicated stratification. All monitored inflows have less conductivity than the water in lake. There is probably strong underground inflow somewhere in the bottom of the lake which is not monitored. The inflow from water basin of the lake has high conductivity in comparison with river water, but less conductivity than water in the lake. Mixing the water levels in the lake is very complicated. At the beginning, the fall-winter mixing occurred and mixed whole water column. The lake had holomictic character. At present, Medard has character of meromictic lake with high conductivity. There is monimolimnion in the lower of hypolimnion. The water surface is continuously rising, but the chemo cline lies at the same level. The water quality of higher levels is getting better mainly due to enough dissolved oxygen (saturated zone) and high pH (round 7,0). Thus Medard lake will be suitable for water sports, fishing etc. In comparison with other post-mining pit lakes (Most, Michal, Milada, Matylda), the inflow water quality is the worst in Medard lake (very high conductivity and metals concentration). But the final water quality in Medard lake is getting better.

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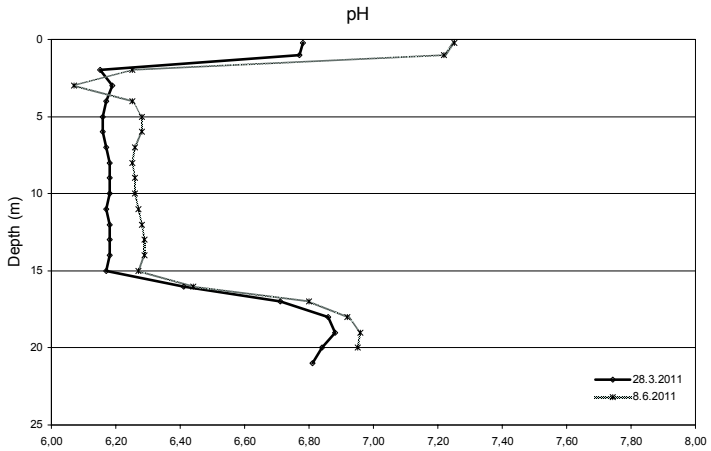

Figure 7 *pH change in Bozi pozehnani lake.*

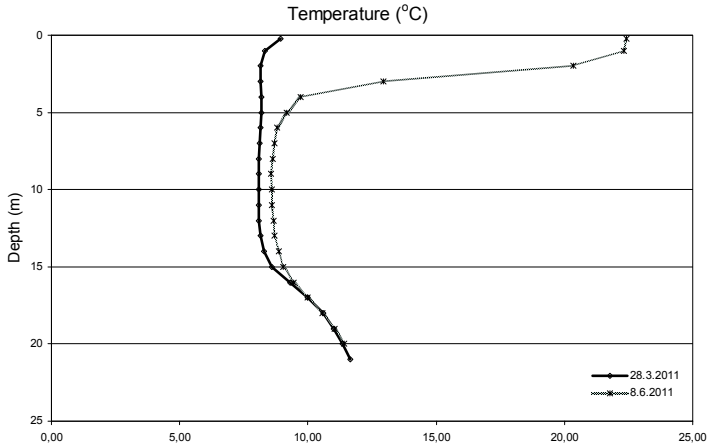

Figure 8 *Temperature change in Bozi pozehnani lake.*

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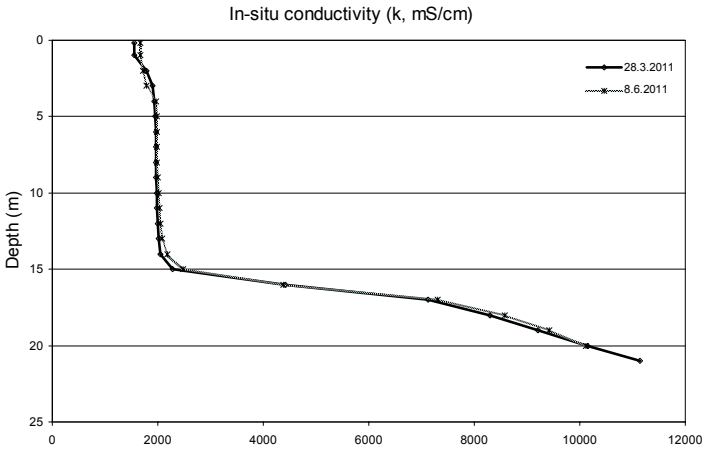

Figure 9 *Conductivity change in Bozi pozehnani lake.*

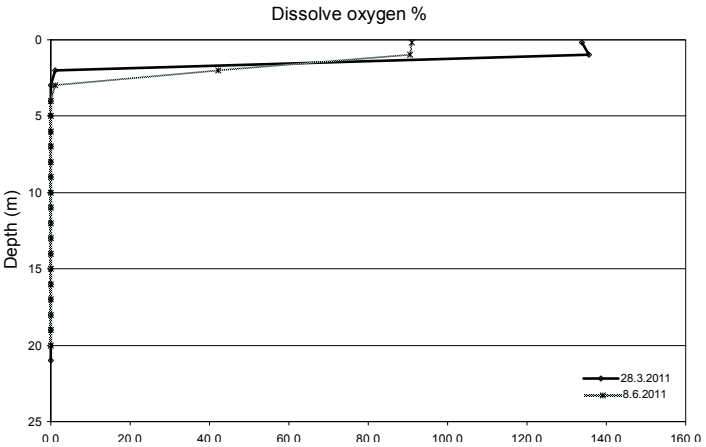

Figure 10 *DO change in Bozi pozehnani lake.*