Mine Water Discharges of the Southern Bavarian Pitch Coal District

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Extended Abstract

In the southern part of Bavaria, several dozen underground pitch coal mines have been mined on an industrial scale between the 19th and the 20th century (Figure 1). Yet, first reports of coal mining date back as early as the 16th century, but their use has been locally restricted. In the 1960ies, due to political and economical reasons, the Bavarian Government and the mine operators decided to close down the remaining mining operations. Consequently, the last Bavarian pitch coal mine at the Hohenpeißenberg closed in 1971.

A total of 17 mine water samples was taken in 2008 and analysed chemically.

Electrical conductivities of the mine waters range between 407 and 4884 µS/cm with a mean of 1458 µS/cm and therefore significantly exceed the maximum electrical conductivity of 207 µS/cm reported for the hydrogeological subunit (Faltenmolasse) in which the mines occur. Also the temperature is slightly increased (a mean of 10.8 °C compared to 8.4 °C), whereas the pH shows no deviation from the normal hydrogeological situation (7.48 compared to 7.45). Those data are a clear indication for an alteration compared to the normal hydrogeological situation in the subunit (Tab. 1).

Based on the Furtak & Langguth classification within the Piper diagram, ten waters are normal earth alkaline waters predominantly bicarbonatic, five are earth alkaline waters with higher alkali amounts predominantly sulphidic, one is a normal earth alkaline water bicarbonatic-sulphidic, and another one is an earth alkaline water with higher alkali amounts predominantly bicarbonatic. All the mine waters falling into the predominantly sulphidic category are at the same time characterized by electrical conductivities above 2 mS/cm and elevated trace element contents. Those waters, emanating from the Marienstein

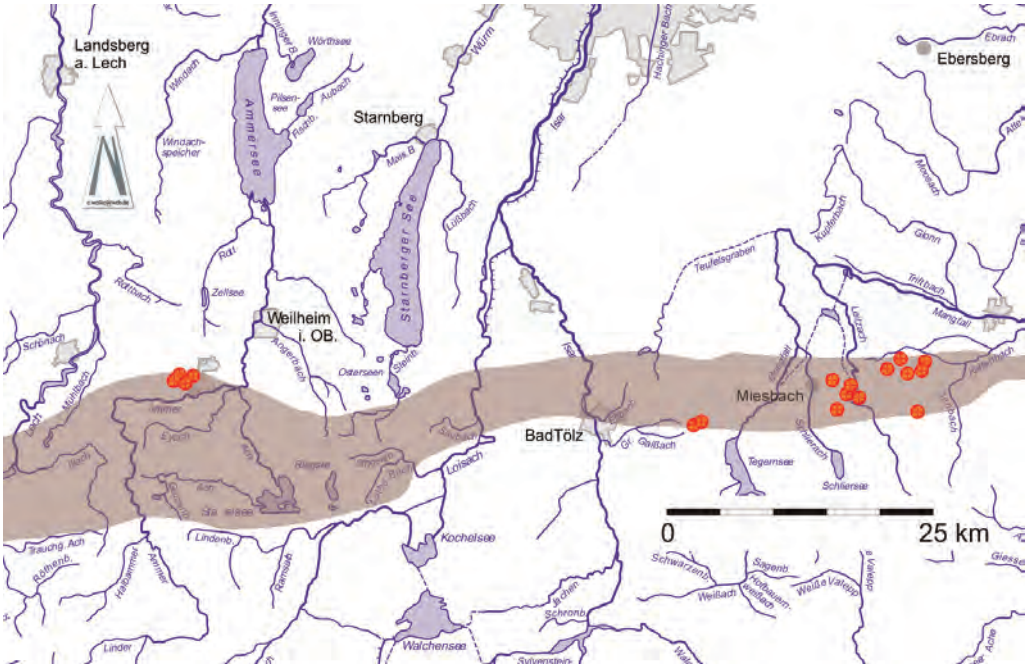

Figure 1 *Location of the Southern Bavarian coal mining district south of Munich. Main locations: circles with red and orange crosses; the main syncline hosting the coal deposits is marked in brown.*

Table 1 *Water chemistry of the investigated southern Bavarian mine water discharges. EC: electrical conductivity; Fe is total iron filtered; n.n.: not detected or below detection limit. Statistical values exclude missing data or data below the detection limit.*

Bezeichnung	T, °C	pH, –	EC, µS/cm	pE	Fe, mg/L	Na, mg/L	K, mg/L	Ca, mg/L	Mg, mg/L	Sr, mg/L	Ba, mg/L	HCO3, mg/L	Cl, mg/L	SO4, mg/L	NO3, mg/L	F, mg/L	As, µg/L
Friedrichstollen	14.5	6.68	4,884	n.n.	12.61	620.0	30.7	397	117.4	8.3	0.22	850	13.8	2,334	n.n.	1.2	23.3
Wasserstollen	11.5	7.24	3,474	n.n.	0.93	304.5	60.9	404	113.3	8.0	0.22	632	97.8	1,884	6.8	0.6	13.8
Peißenberg Tiefstollen	16.8	7.13	3,200	2.81	0.11	351.8	16.7	342	92.8	8.5	<0.6	837	22.3	1,640	1.5	0.7	6.4
Peißenberg Mittelstollen	12.0	7.10	2,480	3.06	5.13	165.8	10.8	406	91.2	8.6	<0.6	577	12.6	1,543	n.n.	0.5	<3.8
Marienstein Halde	10.2	8.34	2,409	7.10	0.06	83.5	195.0	217	101.9	2.8	0.22	155	2.5	1,261	29.0	0.9	<2.4
Peißenberg Sulzer Stollen	8.5	7.60	1,007	4.56	0.05	15.6	2.3	147	41.5	1.4	<0.6	350	7.2	286	1.5	0.2	<3.8
Achtalschacht (lab results)	24.4	7.06	908	n.n.	< 0.05	113.1	4.2	65	21.9	1.0	< 0.1	n.n.	6.4	49	n.n.	0.7	< 2.1
Alter Auer Erbstollen	n.n.	7.47	849	2.75	<0.05	24.6	2.8	119	30.1	1.1	0.64	495	23.3	12	0.9	0.3	<2.4
Phillippstollen	9.4	7.12	773	n.n.	0.33	28.0	3.9	111	21.8	1.0	<0.2	333	8.8	94	1.4	0.3	<2.4
Auer Hauptstollen	9.9	7.10	748	1.86	0.25	22.7	2.5	106	23.7	1.0	<0.2	461	5.3	17	0.3	0.3	<2.4
Kemathstollen	9.6	7.75	675	5.21	0.06	7.9	2.6	106	24.6	0.9	0.38	431	10.8	14	0.4	0.2	<2.4
Marienstein Marienstollen	7.2	7.72	634	4.01	< 0.05	23.6	2.0	81	21.0	0.6	< 0.1	326	6.7	76	4.4	0.2	< 2.1
Deisenrieder Stollen	8.4	7.74	612	10.33	0.04	4.9	1.0	92	21.5	0.4	<0.6	398	3.8	25	6.4	0.2	<3.8
Eckersberger Stollen	7.4	7.71	603	5.83	<0.05	3.2	0.8	97	20.0	0.4	0.45	325	2.3	32	17.3	0.2	<2.4
Peißenberg Hauptstollen	8.0	8.28	568	8.89	<0.04	9.4	0.9	82	18.3	0.2	<0.6	389	19.0	15	7.8	0.2	<3.8
Bärenschützstollen	9.5	7.09	560	3.50	0.82	2.5	1.3	101	14.4	0.7	0.26	359	1.5	42	0.3	0.2	<2.4
Leitsachstollen Querschlag	5.3	8.08	407	n.n.	0.06	1.0	0.7	65	13.9	0.2	0.27	243	1.2	17	7.5	n.n.	<2.4
Means of the above	10.8	7.48	1,458	4.99	1.70	104.8	19.9	173	46.4	2.6	0.33	448	14.4	549	6.1	0.4	14.5
Standard deviation	4.6	0.47	1,325	2.62	3.72	170.3	47.7	128	38.8	3.3	0.15	193	22.6	815	8.1	0.3	8.5
min	5.3	6.68	407	1.86	0.04	1.0	0.7	65	13.9	0.2	0.22	155	1.2	12	0.3	0.2	6.4
max	24.4	8.34	4,884	10.33	12.61	620.0	195.0	406	117.4	8.6	0.64	850	97.8	2,334	29.0	1.2	23.3

pile, Peißenberg Mittelstollen, Peißenberg Tiefstollen, Wasserstollen, and Friedrichstollen can therefore be described as classical mine waters. Their As mass concentration reaches up to 23 µg/L, Cr 6 µg/L, Ni 23 µg/L, Cu 5 µg/L, and Co 8 µg/L.

pH values range between 6.7 (Friedrichstollen) and 8.3 (Marienstein pile). While the pH of the Friedrichstollen is clearly influenced by pyrite oxidation, the Marienstein pile shows an influence from basic processing chemicals. All other pH-values range between 7.1 and 8.3, thus being well buffered in the bicarbonate buffer range, which might be expected from the local geological situation.

During the field investigation in spring and summer, the flows from the dewatering adits ranged between 1 and 2100 L/min with a mean of 180 L/min (Tab. 2). The largest flow is that of the Friedrichstollen, discharging into the river Leitzach, being also the dewatering adit with the highest electrical conductivity, sulphate, arsenic, cadmium, and iron concentrations. Its annual load is 14 t of Fe, 26 kg of As, 14 kg of Ni, 4 kg of Cu and approximately 1 kg of the before mentioned elements.

Name of Discharge	Flow. L/min	pH
Achtalschacht	<< 1	7.06
Alter Auer Erbstollen	10.3	7.47
Auer Hauptstollen	5	7.10
Bärenschützstollen	4.81	7.09
Deisenrieder Stollen	80.23	7.74
Eckersberger Stollen	1	7.71
Friedrichstollen	2092.8	6.68
Kemathstollen	3.14	7.75
Leitsachstollen Querschlag	7.35	8.08
Marienstein Halde	12	8.34
Marienstein Marienstollen	3.3	7.72
Peißenberg Hauptstollen	2.6	8.28
Peißenberg Mittelstollen	159.6	7.10
Peißenberg Sulzer Stollen	43.6	7.60
Peißenberg Tiefstollen	217.2	7.13
Phillippstollen	5	7.12
Wasserstollen	189.6	7.24

Table 2 *Sampled mine water discharges with flow and pH on the day of sampling in Spring 2008.*

During the field investigation local informants reported about "red" water near the abandoned Achthal shaft. This shaft's pit head has an elevation of about 550 masl (meters above sea level) and is connected to the Auer dewatering adit which discharges 1.7 km to the North-East at an elevation of 510 masl. At both locations the mine water had a noticeable H_2S smell and a low redox potential (110–170 mV). Due to the fact that the mine water discharges at the pit head of the Achthal shaft, it might be assumed that the Auer dewatering adit is broken in. Should the pressure behind the blockade further increase, an outburst at the Auer dewatering adit with an ensuing pollution of the receiving brook might not be excluded.

Most discharges cause a visible staining of the receiving streams and at least in one case informants reported an outburst of the Friedrichstollen with a subsequent fish dying. Therefore, the local authorities should ensure that the mine waters are treated accordingly, if possible with passive treatment systems (e.g. settling ponds with constructed aerobic wetlands) which would suit to the touristic region of Upper Bavaria.