Evaluation of a Short-Term Increased Water Influx in a Mine Drainage Facility of a Former Hard Coal Mine

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Abstract

RAG AG currently operates a mine drainage facility at the abandoned coal mine Amalie in the city of Essen, Germany. Throughout April 2020 a short-term increased water influx occurred at this mining site at one dam. To identify on-going processes in the mining plant water chemistry was analysed and investigated. One result of the investigation was, that the break of a dam lead to a new water influx into the water system of the mine. This new water flux resulted in a permanently higher amount of water entering the mine. Chemical analysis of the water also showed a change in composition. The amount of dissolved salts increased significantly. This provides more information on processes in abandoned parts of the mine and helps to improve our predictions of the subsurface water system.

Keywords: Increasing Water Influx, Hydraulic Prospecting, Mine Drainage Facility

Introduction

RAG AG currently operates several mine drainage facilities throughout the former coalmining area Ruhrrevier in western Germany. One drainage facility is located at the abandoned coal mine Amalie in the city of Essen, Germany. The drainage facility at this mining site is in operation to protect further surrounding abandoned mines. Two shafts and about 2 km of drifts are still in use underground. Water is pumped from behind two subsurface dams and collected in a pumping chamber. Water from different parts of the mine mixes in the pumping chamber and is then pumped above ground. One dam, called "W2", is draining the northern part of the former mine. The other dam, called "W1", is draining the southern part of the abandoned mine. In general water volume measurements and samples for chemical analysis are taken above ground from the "mixed" water.

Throughout April 2020 a short-term increased water influx occurred at this mining site at dam W2. The pumped water volume in 2020 is shown in Figure one. The graph shows that within two days in April the pumped water volume increased from 13,500 m³/d up to 23,000 m³/d. In the beginning not all the water could be pumped away. A water column built up behind dam W2. To avoid overpressure on the dam an additional pump was activated. This resulted in a maximum pump volume of 27,800 m³/d. After pumping the water column from behind W2, a water volume of approximately 24,500 m³/d was pumped for about 4 days. The end of this incident was marked by a decrease in volume within 2 days. Although the decrease wasn't as high as the increase, the main incident was over. The decrease continued slowly until the end of the year.

The main question that presented itself when investigating this incident was if a mine cavity had run empty after a dam breakdown or were there other processes running? To answer this question, it is important to investigate the water volume pumped of the two dams and the water chemistry of dam W1, dam W2 and the mixed water.

Methods

At first, water quality of the total water volume at the surface and dams W1 and W2 was examined by taking samples at the same day. Sampling took place six times from April to November 2020, as indicated with the black circles in Figure one. The major cations (sodium, potassium, calcium and magnesium) and the major anions (chloride, sulphate and hydrogen carbonate) were

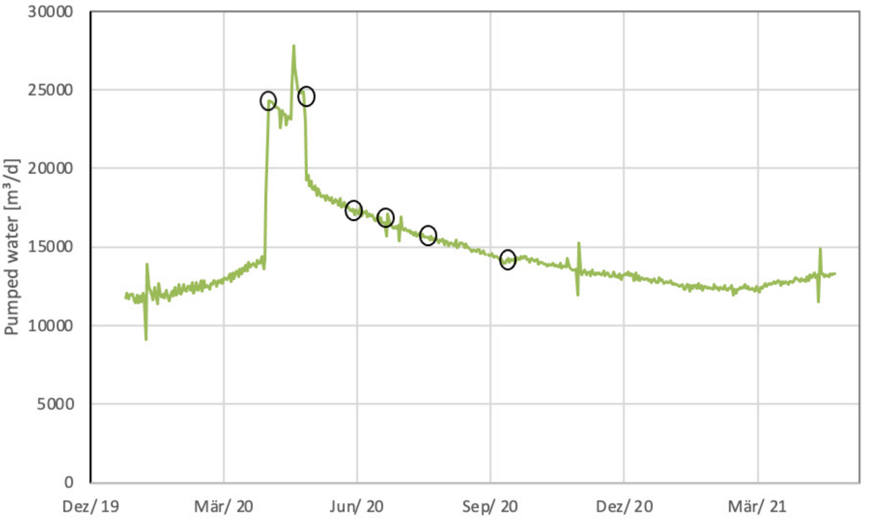

***Figure 1** Daily amount of pumped water of mine drainage facility Amalie in 2020 with dates of sampling in yellow circles.*

***Table 1** Chemistry results of mixed water in the total Water flow of Amalie.*

Amalie – total Water composition							
Date		01.04.2020	29.04.2020	28.05.2020	04.06.2020	09.06.2020	10.11.2020
Electrical conductivity	µS/cm	19100	22500	16300	21100	19100	18800
ph volume	[-]	7	7,1	7,5	7,3	7,2	7,1
Sodium (Na)	mg/l	3880	4570	343	4170	3800	3910
Potassium (K)	mg/l	68	72	54	57	62	65
Calcium (Ca)	mg/l	225	411	302	427	392	417
Magnesium (Mg)	mg/l	76	134	113	131	135	130
Chloride	mg/l	6420	7870	5520	7350	6750	6570
Sulphate (SO4)	mg/l	304	218	256	223	239	210
Hydrogen carbonate (HCO3)	mg/l	1100	780	800	770	780	800

***Table 2** Chemistry results of mixed water in the total Water flow of dam W2.*

Dam W2							
Data		01.04.2020	29.04.2020	28.05.2020	04.06.2020	09.06.2020	10.11.2020
Electrical conductivity	µS/cm	30000	32101	76600	76200	75400	79200
pH value	[-]	6,9	7	6,8	6,7	6,7	6,5
sodium (Na)	mg/l	6440	6623	16400	15900	16600	18900
Potassium (K)	mg/l	88	98	236	178	226	256
Calcium (Ca)	mg/l	347	562	1310	1430	1330	1790
Magnesium (Mg)	mg/l	119	178	392	386	428	508
Chloride	mg/l	10600	11521	31200	30600	30600	33000
Sulphate (SO4)	mg/l	341	150	22,1	16,9	21,5	18
Hydrogen carbonate (HCO3)	mg/l	1200	732	490	480	460	490

Table 3 Chemistry results of mixed water in the total Water flow of dam W1.

		Dam W1					
Date		01.04.2020	29.04.2020	28.05.2020	04.06.2020	09.06.2020	10.11.2020
electrical conductivity	µS/cm	2830	4670	3180	3160	3090	3540
pH Value	[-]	7	7	7,3	7,1	7,2	7
Sodium (Na)	mg/l	468	757	483	513	509	625
Potassium (K)	mg/l	22	24	21	19	22	23
Calcium (Ca)	mg/l	111	131	118	116	112	122
Magnesium (Mg)	mg/l	46	53	48	47	51	51
Chloride	mg/l	374	1090	419	463	451	588
Sulphate (SO4)	mg/l	264	344	262	284	268	263
Hydrogen carbonate (HCO3)	mg/l	870	870	860	860	860	890

Table 4 Results – Calculation water amount provided by dam W2.

Percentage of W2 water [%]	9%	55%	15%	25 %	20%
Amount of W2 water [m³/min]	1 m³/min	8,437	1,8	3,05	2,34
Total Amount of water	11 m³/min	15,3 m³/min	12,0 m³/min	12,2 m³/min	11,7 m³/min
Date	01.02.2020	01.04.2020	28.05.2020	04.06.2020	09.06.2020

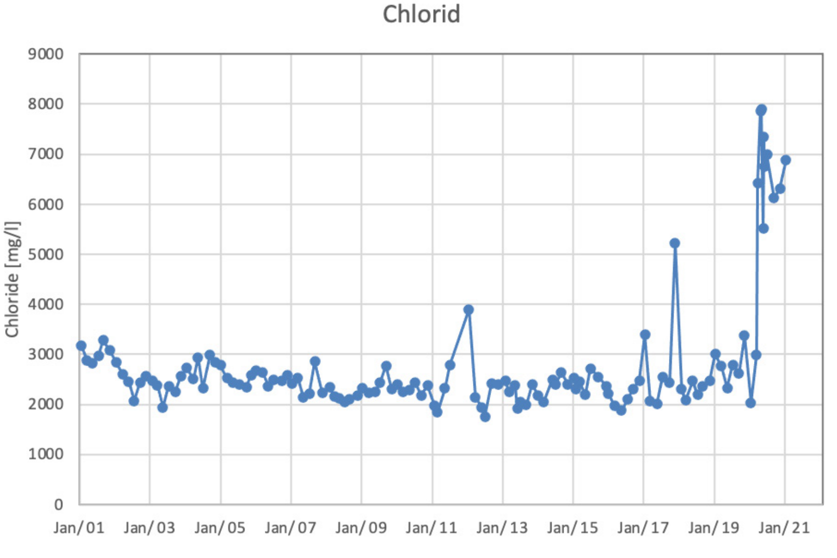

***Figure 2** Chloride concentration in the mixed water at the mine drainage facility Amalie of the last 20 years in mg/l.*

determined. Results are presented in Table 1 to 3 sorted according to the sampling sites.

We calculate the ratio of water pumped from the dam W1, W2 and the mixed water. We did this by making a mixture calculation based on the chloride content of three water types (dam W1, dam W2 and mixed water). The results are shown in Table 4. Here you can see an estimated amount of 9% W2-Water before the incident. Throughout the incident the water volume increases up to 55% of the total water volume. Afterwards an average of 15 to 20% of the total water amount is provided by dam W2.

The chemical composition changed completely during this incident as well. As an example, chloride is shown in Figure two. It's obvious that higher chloride values are detected during the incident and afterwards. The high amounts of chloride remain constant until January 2021, also the water volume decreases. Therefore, it is important to look at the development of chloride at the dams in relation to the total chloride concentration. This is shown in Figure 3.

The graphs of dam W1 and of total water amount stay on the same level over time. Major changes of chloride are detected of the dam W2 during decrease of the water volume. Like chloride the other ions change as well. Mainly effects are seen within the sulphate results. This is shown in Graph 4. These lower sulphate results need to be related to higher Strontium and Barium values. Additional

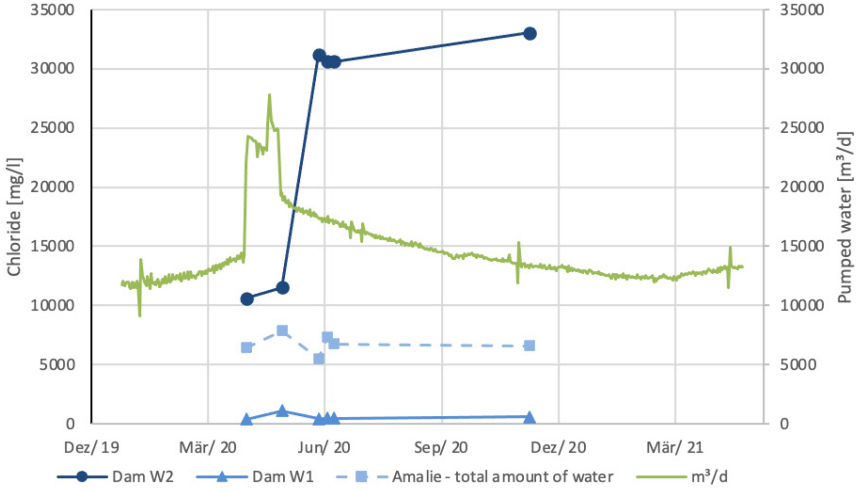

Figure 3 *Chloride concentration in 2020 split on the three sampling points in blue, the total amount of pumped water in with the green graph.*

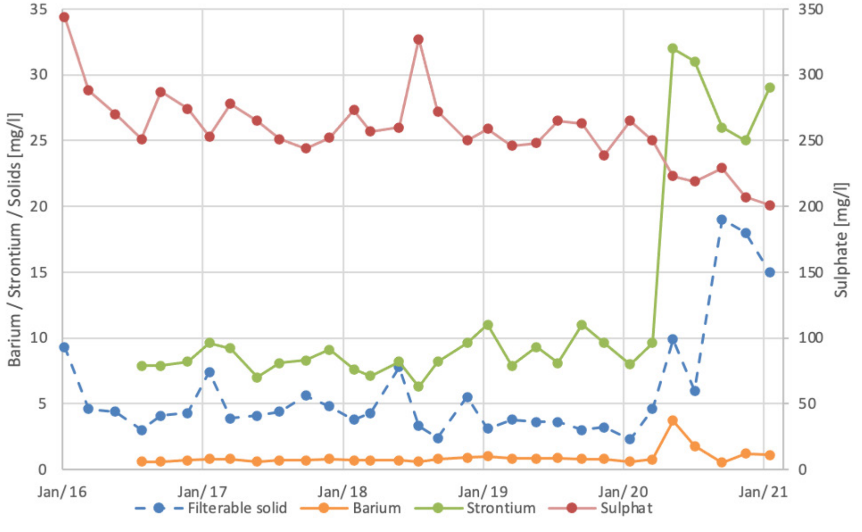

Figure 4 *Impact of barium influence with the new influx in mg/l.*

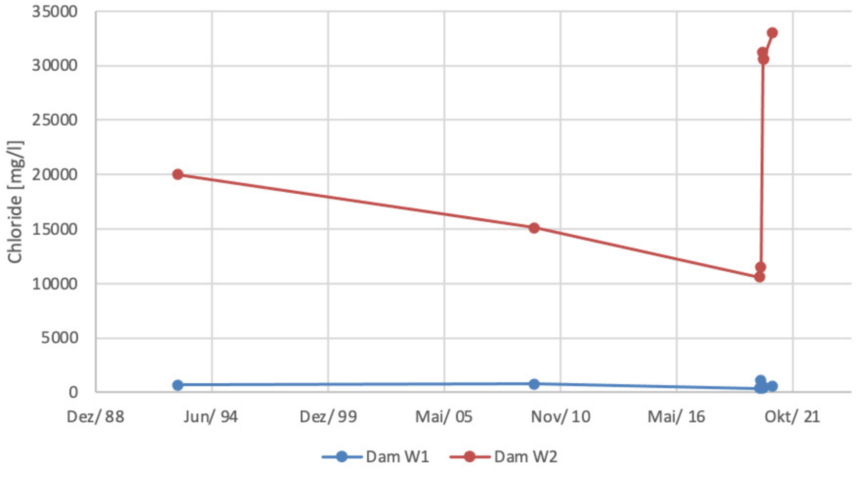

***Figure 5** Development of chloride [mg/l] at the dam W1 and W2 over the last 30 years.*

chemistry data were researched. At least 2 datasets where found from 2009 and 1992 (Wedewardt), which both show values below the ones of the incident. The Graph 5 shows the chloride data.

Conclusions

Chemistry data and calculations paint a clear picture. The mixing calculations indicate a draining of a mining cavity at first. It can be seen by the high percentage of over 50% of W2-dam water volume in the mixed water. High chloride concentration in the mixed water is a result of the main influence of W1-water at first. As the cavity is drained, it's obvious, that the breakdown of a dam lead to new influxes from this part of the mine with dramatic increase of dissolved substances. Taking older data into account a different picture can be painted. As the Figure 5 shows the chloride concentrations decrease over the last thirty years and increases within two months. One explanation might be that a part of the mine develops on its own. Therefore, a water column forms there. Influxes out of deeper parts of the mine are blocked out. The water content of the dam W2 decreases therefore over the years. With the breakdown of a dam water empties out the mining cavity. This leads to influxes out of deeper parts of the mine which now have become part of the water system again. This is indicated by a fundamental change in chemical composition after the decrease of water influx. The new influx shows higher dissolved substances and a new barium dominance as well. Barium sulphate precipitation corresponds to higher suspended solids and sedimentary deposits in water pipelines. A slightly higher percentage of the W2 water within the mixed water also indicates this.

This new information gives us a better understanding of underground processes, which affect not just the small area of the mine drainage facility Amalie, but also allows us to upscale to larger areas and time spans.

References

Wedewardt, M. (1995); Hydrochemie und Genese der Tiefenwässer im Ruhr-Revier, DMT-Berichte aus Forschung und Entwicklung, A-34 pp.