Mine water concept in detail – A case study of closing a German coal mine at Ruhr district

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Abstract A concept of closing a German hard coal mine includes the decommissioning of underground facilities and addresses all matters of environmental protection in a long term view. Therefore the concept has to describe the decommissioning of production, the separation of mine field infrastructure, the preparation of roadways and the mine water management. The report gives a short overview of the mine layout and geological circumstances, followed by a description of measures for preparation prior to closing including operational aspects and regulatory approvals up to required monitoring measures.

Key words Mine closure, Post-mining water management, hard coal mining

Introduction

RAG Aktiengesellschaft (RAG) is responsible for finishing hard coal mining in Germany up to the year 2018 based on long term contracts and agreements. RAG is following a detailed concept of mine closure for each mine and also considering generic regional aspects. This paper gives an exemplary overview to the closing of an underground hard coal mine in the Ruhr area of Germany. At first some fundamental parameters of the geological and geometrical situation are described. For the description of procedure it is also necessary to mention some important legislative requirements. Based on the regional concept of mine water management the process of mine closure has to fulfil a lot of specific demands. In the following some examples of applied methods and operations regarding mine water management are pointed out.

Basics for closure of a hard coal mine in the Ruhr area

Geological overview

Hard coal deposit of the Ruhr area is located in Carboniferous strata. In the South of the Ruhr district these strata are directly cropping out to the surface. Strata are dipping to the North and the overburden of the Carboniferous is consisting of Tertiary and Quaternary strata.

In total there are approximately 200 seams in Carboniferous rock with a thickness between a few centimeters up to 5 meters. In the northern area of the coal field the seams are located in a depth of approximately 1000 to 1500 meters.

Geometrical and operational parameters of a typical mine

A typical hard coal mine of today consists of several shafts and a large number of roadways in the underground. An area of 20 to 30 square kilometers is covered, more than 130 kilometers of roadways in a depth between 800 meters and 1500 meters describe the scale of a typical mine in numbers.

Legislative basics

Main basics for mining activities in the Ruhr area are formed by a federal legislation and the country codes of North Rhine Westphalia. These laws rule mining in production as well as mine closure. For mine closure additional recommendations of European, federal and local demands are taken into consideration, because danger by post mining risks has to be avoided.

The main challenges of mine closure are:

- prevention of uncontrolled gas emissions,
- control of mine water level with respect to other groundwater levels,
- save of drinking water quality,
- prevention of damage by movement of the ground.

Procedure of closing

Elements of mine water management are applied during production time as well as in time of closure. Important is a continuous observation of mine water quality at any point of inflow in the underground. Due to this demand underground probes are taken and analysed for specific physical and chemical parameters. Table 1 gives a list of parameters that are analysed in standard sampling. The column PP1 describes the standard test range, PP2 minimized simplified tests and PP3 to PP5 additional tests for cases of suspicion.

Table 1 *Standard cathegories of testing procedure for mine water probes (IHS 2007).*

Parameter		PP1	PP2	PP3	PP4	PP5
on-site	colour	x	x			
	clouding	x	x			
	smell	x	x			
	temperature	x	x			
	pH-value	x	x			
	electric conductivity	x	x			
main components	evaporation residue	x				
	total hardness	x				
	Natrium	x	x			
	Calcium	x				
	Magnesium	x				
	Potassium	x				
	Chloride	x	x			
	Sulfate	x	x			
	Hydrocarbonate	x				
minor compnents	Ammonium	x				
	Nitrate	x				
	Nitrite	x				
	Barium	x	x			
	Strontium	x				
	Iron	x	x			
	Manganese	x				
specific extraordinary loads	Radium 226			x		
	Radium 228			x		
	Sulfide					x
	Zinc				x	
	Lead				x	
anthropogenic loads	COD	x	x			
	Phosphor	x				
	Hydrocarbons	x				
	Absorbable organic halogen	x				
	PCB	x	x			
	PCB substitutes	x	x			

Figure 1 gives an exemplary overview to the points of geogenic water inflow to the mine infrastructure at Auguste Victoria mine. The perspective view includes remarks by arrows and a table of water flows for each point. In total the inflow amounts 156 m³ per hour. Different colours indicate different levels of roadway infrastructure. The shafts are marked as AV 3/7, AV 6, AV 8 and AV 9 and WU 1/2 (adjacent mine).

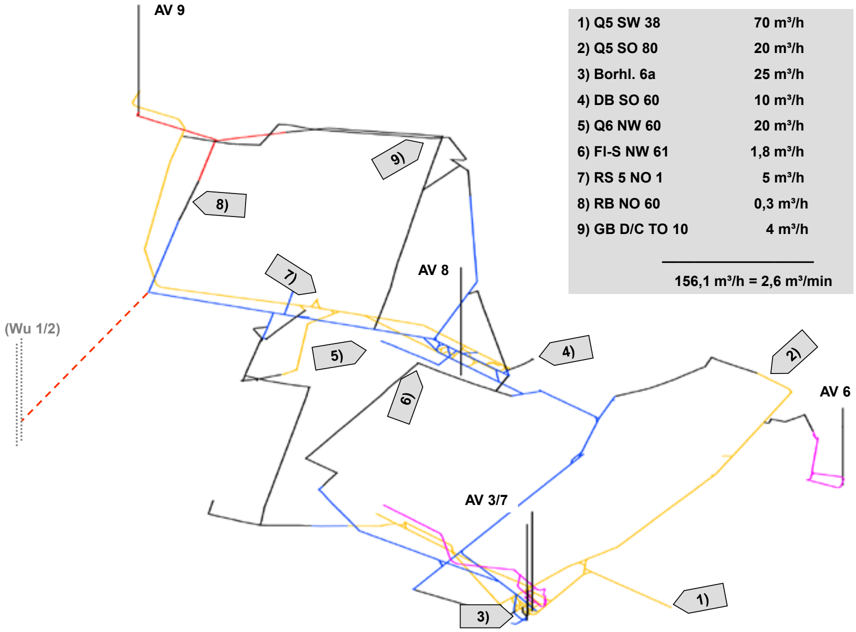

Figure 1 *Perspective view on water inflow to Auguste Victoria mine infrastructure*

At several places highly mineralized geogenic water flows into the mine. This type of water has often a high content of barium. Different water inflow, mostly from shallow depth, has a different chemical composition and contains a high level of sulfate in most cases.

At the place of conduction of this two different types of water barium sulfate is precipitated. This chemical reaction is having a significant negative influence on the condition of pipelines and pumps. Based on this knowledge RAG uses former mining panels as areas for sedimentation. Therefore this water types are let into these rooms of retention separately. There the salt is precipitated and the clean water is pumped to surface.

After finishing of roadway heading and coal production all required roadways are prepared as water gateways. This includes examination of former workstations for pollutants, installation of a pipeline network and clearing up the roadways. The pipelines are installed to ensure a minimum shape for water conduction even if the roadway support collapses. For achieving a drainage effect, approximately every 100 meters a case filled with gravel covers a point of inlet to the pipes (fig. 2).

Figure 2 *Example of pipeline installation underground.*

In the first phase of closure the areas of former mining excavations are normally separated, when they are not necessary for infrastructure and ventilation any more. The closure is realized by the installation of concrete structures within the roadway. The structure is dimensioned to prevent mine water inflow as well as gas explosion. The unventilated area behind the concrete wall is characterized by a rising content of methane gas.

A final operating plan, that must have an official statutory approval by the mining authority, is the basis for this procedure.

Connected with this approval commonly specific auxiliary conditions are formulated by the authority, resulting on risks that are recognized and documented in third party expertises. The verification of each process and execution of specific monitoring measures have to be implemented in a final documentation of realization.

Preparation of shafts

Long-term mine water management is aiming on using old shafts as well stations. The regional concept allows minimizing the number of well stations. Because of this concept the underground pumping stations will be substituted by well pumps within the shaft. For this the complete shaft installation has to be recovered and a vertical pipe for each required pump gets installed. A pillar of concrete is filled into the not needed shape of the shaft. The length and static construction of the pillar is depending on specific local parameters for each shaft. The detailed technical planning is aiming on long-term stability, avoiding uncontrolled gas emission and explosion prevention besides economic pumping processing.

Figure 3 shows on the left side a picture of a pumping station in the underground. On the right side figures a scheme of the closed underground roadway system, the pump and pipes for well operation.

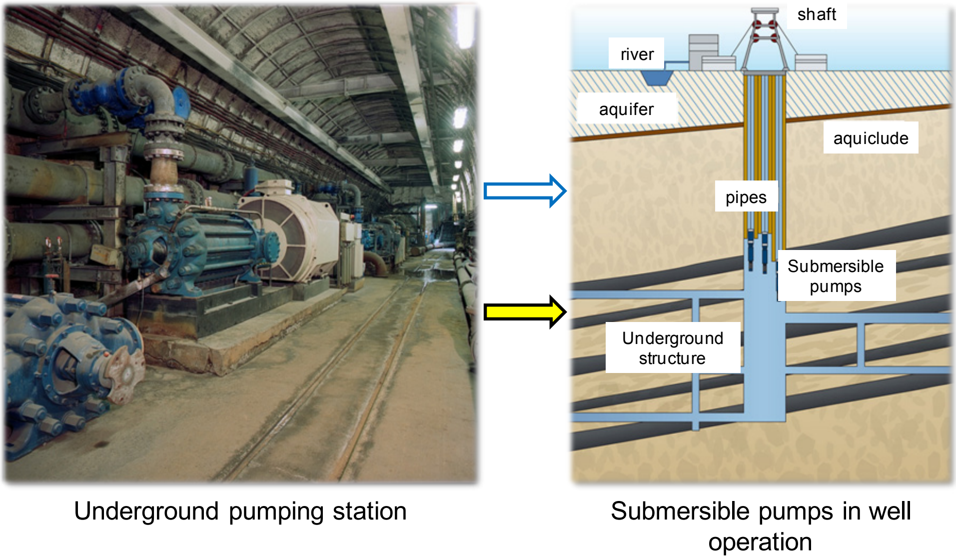

Figure 3 *Preparation of shafts for well pumping stations*

Operational matters

A mine with a working area of 60 km² cannot be closed in one step. So minimizing of the open underground area is going on stepwise. When an area is prepared for closing and all of the machinery is deconstructed, a barrier dam is constructed in concrete material. This barrier contents pipelines for dewatering measures, must be gastight and also has to be dimensioned to allow explosion protection. If a dam is located in the later water gateway, it must be reopened when the next following underground area is closed.

The preparation for closing starts long before the end of production. Figure 4 shows a perspective view on Auguste Victoria mine 3 years and 2 years before closing. Still active districts in the North (blue circles) are running while other parts of the mine (West and East) are abandoned in that phase (green circles).

Even in that time of closure a roadway was driven to the adjacent mine (grey circle). In the regional concept of mine water management this path is required for underground water flow and finally reduction of well station number.

A monitoring of mine water level is applied to proof the results of predicted rise of water level. The prediction is done by a special software system "Boxmodell" which was designed in cooperation with DMT company. The model gives a prospect on several parts ("Wasser-

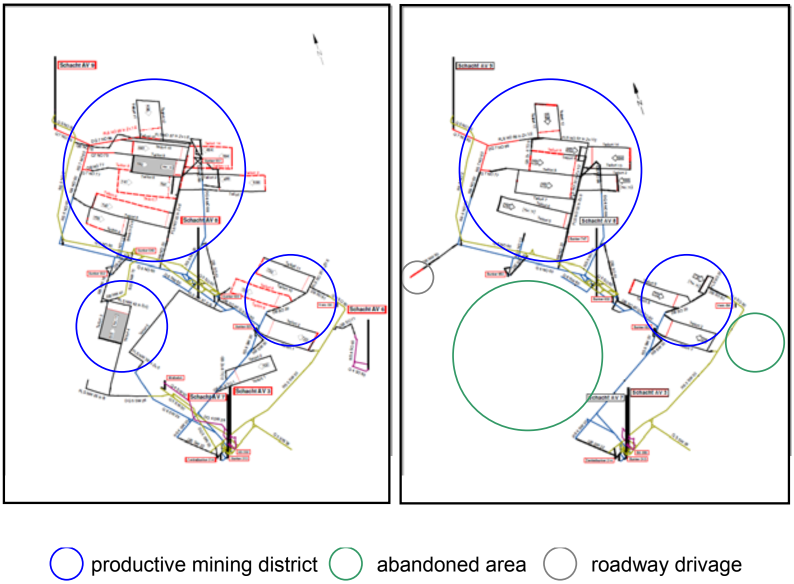

Figure 4 *Exemplary comparison of retreating areas in a mine*

provinzen") within a regional model and contains several boxes for simulating the mine water management. The modelling is done with respect to several geometrical, physical and chemical parameters and is recalibrated consequently by monitoring results and water analysis. Figure 5 gives a prospective view on the model of the Ruhr area in total. Each box is vertically subdivided into several plates. Each plate provides an individual set of modelling parameters. Figure 6 shows a comparison of forecast and measured data of water level. The graph shows different points/areas as arrays printing (time series) and dots as results of monitoring.

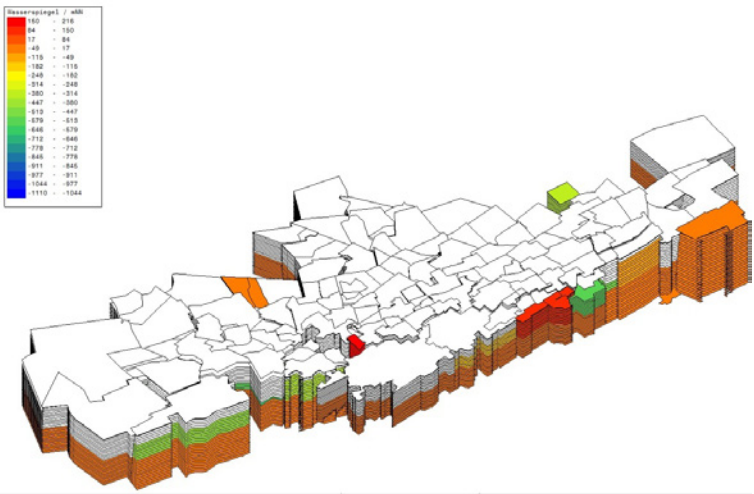

Figure 5 *Boxmodel for simulation – example Ruhr area (DMT, Eckart et al.)*

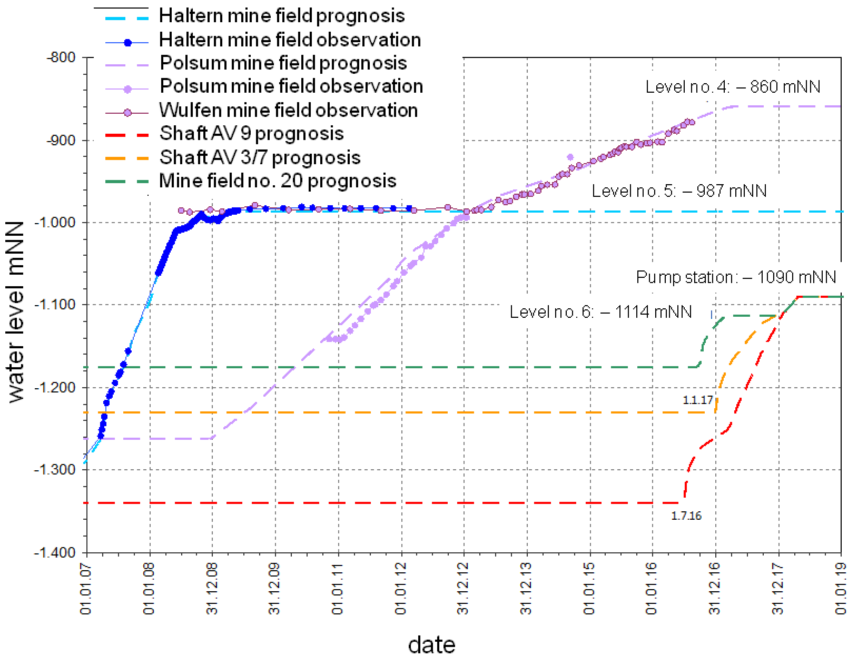

Figure 6 *Simulation of exemplary mine water levels and monitoring results (DMT)*

Conclusions and outlook

Closing of an underground mine is a long-term project. Beside RAG as the mining company it requires teamwork of water scientists, mining administration, constructors, planning engineers and lawyers for cooperation. Since the year 2007 RAG follows regional conceptions and did close several mines successfully. Underground roadways were used as water gateways to minimize the number of pumping stations. To get optimized results of later activities for pumping all water gateways are prepared carefully with respect to chemical composition of different mine water qualities. The described example gives an overview to a wide spread of measures that are executed for closing and realisation of regional water management. Up to now RAG did proof the success of the work for each mine by results of monitoring.

When the last German hard coal mine will close in 2018 all remaining pumping stations will be optimized for long-term run. This means to prepare additional old shafts for well pumping stations and proof successful realisation of the mine water concept by ongoing monitoring processing. Besides common monitoring from surface also modern underground probes will be used for long-term measurement of in-situ water parameters.

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