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Study on Mine Water flooding that occurred in Hard-Coal Mining Areas in Germany and Europe

The article provides essential information about the experience and knowledge of the mine water flooding in hard-coal mining areas in Germany and Europe. The study is based on extensive literature research and separate coal-mining district inspection.

1 Introduction

As commissioned by RAG AG, a study was carried out on mine water flooding that occurred in hard-coal mining areas in Germany and Europe. When investigating the hard-coal mining areas, special emphasis was placed on gaining insights from the rise of mine water levels. Likewise, the study documents the heaving and subsidence that accompanied the rise of mine water levels. The following chapters will present the results of the study.

2 Hard-coal mining areas investigated

In total, 21 hard-coal mining areas across Europe were analysed; 9 of those 21 are in Germany. Table 1 lists the hard-coal mining areas that were investigated.

The following criteria were distinctly applied when analysing the individual hard-coal mining areas:

- Mining period
- Mining depth
- Size of mining area
- Deposit geology
- Overburden geology
- Experience from mine water retention and flooding
- Monitoring
- Particular features of the deposits
- Measures for long-time water retention

In addition to the hard-coal mining areas investigated, other hard-coal mining areas are also documented as part of the research carried out; Table 2 lists those for a completeness of results.

3 Insights gained from the rise of mine water level in flooded mining areas

Regarding the rise of mine water levels, the following insights result from the study carried out with relation to the mining areas investigated:

- The rise of mine water levels decisively depends on the natural and hydro-geological conditions of both the deposit and its overburden.
- In the actual deposit, the mine water usually rises more quickly than in the overburden. In average, typical volumes are:
  - between 30 m/a and 50 m/a
  - between 5 m/a and 15 m/a in deposits/overburden of low permeability
  - up to 200 m/a in deposits/overburden of high permeability and in deposits without overburden.
- The documented leaks of mine water are mostly related to the wrong assessment of the migration structures that exist. Moreover, inadequate monitoring meant that the actual rise of mine water was not recorded and no appropriate measures could be initiated in due time.
- One particular problem is caused by old mining that happened at or close to the surface and that is often insufficiently documented: here, it is very difficult to forecast the migration structures that occurs due to the rise in mine water levels. The same applies to mining cavings.

Country	Mining Area	No.	Deposit
Germany	Ruhr	D1	Upper Carboniferous
	Aachen and Erkelenz	D2	Upper Carboniferous
	Saar	D3	Upper Carboniferous
	Ibbenbueren	D4	Upper Carboniferous
	Zwickau	D5	Upper Carboniferous
	Lugau Oelsnitz	D6	Upper Carboniferous
	Doehlen Basin // Freital	D7	Permian
	Southern Bavarian Pitch Coal	D8	Tertiary
	Deister	D9	Lower Cretacious
Netherlands	Southern Limburg	NL1	Upper Carboniferous
United Kingdom	Yorkshire	GB1	Upper Carboniferous
	Lancashire	GB2	Upper Carboniferous
	South Wales	GB3	Upper Carboniferous
France	Lorraine	F1	Upper Carboniferous
	North – Pas-de-Calais	F2	Upper Carboniferous
Belgium	Kempen	B1	Upper Carboniferous
	Liège	B2	Upper Carboniferous
	Hennegau	B3	Upper Carboniferous
Poland	Lowe Silesia	P1	Upper Carboniferous
	Upper Silesia	P2	Upper Carboniferous
	Lublin	P3	Upper Carboniferous

Table 1 / investigated hard-coal mining areas in Germany and Europe.

Country	Mining Area	Deposit
Germany	Osnabrueck Piesberg Hueggel	Upper Carboniferous (Carbon raise drift)
	Schaumburg district	Lower Cretaceous
	Baden-Wuerttemberg • Baden Baden • Kinzigtal (betw. Offenburg & Lahr)	Upper Carboniferous
	Bavaria: • Kronach district: • Stockheim Reitsch Upper Palatinate: • Erbendorf	Upper Carboniferous
	Area around Hall/ Saale • Wettin • Ploetz-Loebejuehn	Upper Carboniferous
	Ore Mountains Basin: • Borna-Ebersdorf • Hainichen • Floeha Basin	Upper Carboniferous

Table 2 / other hard-coal mining areas in Germany

- During the research work no evidence was found that the rise in mine water levels leads to an increased escape of mine gas at the surface of the terrain.
- In several mining areas, the rise of mine water levels leads to an increase in density between the specifically denser, i.e. heavier and more mineral-containing, mine waters and the lighter and less mineral-containing mine waters of the overburden. The knowledge gained allows the conclusion that the formation of a density stratification is to be expected in several areas (Ruhr, Saar, Ibbenbueren, Lorraine, Liège).
- Many mine waters gain extremely acidic qualities due to the rise as well as increased levels of iron and sulphate which can be related to the pyrite oxidation. Usually such waters are treated or processed before they are discharged into natural watercourses (United Kingdom, Lorraine, Ibbenbueren).
- A lack of treatment plants led to pollution of natural watercourses by mine water leakage, particularly in the United Kingdom.
- Currently, no pollution of natural groundwater aquifers or an impairment of drinking water levels are documented that were caused by a rise in mine water levels.
- Main adits often dewater unchecked into the receiving waters; here, the quality and quantity of the waters are often as unknown as the technical condition of the adits.

4 Insights on heaving and subsidence caused by the rise in mine water levels in flooded mining areas

The study carried out leads to several insights on the heaving and subsidence that occurs as part of the rise in mine water levels. Principally, a rise in mine water levels means that heaving of the terrain has to be expected. On the one hand, this is related to the natural upwelling of the rising mine water, and, on the other hand, to the water absorption of the solid rock mass that is caused by the rise in water level where in particular the fine-grain particles react with different swelling amounts.

The apparent opposing force are settlements which occur in mined structured (goaf) due to the rise in mine water levels. Obviously, materials are shifted in mining cavings.

Table 3 lists the terrain changes that were researched for the individual mining areas, i.e. the amounts of heaving and subsidence that occurred in the wake of mine water rising.

The values stated are partly based on the classical levelling model and height observation at the surface, and also on data derived from satellite images have been used.

According to the present state of knowledge, the heaving caused by the mine water rise is mostly even and at the same level and thus overall does not cause damage to the continuance. Only in the Erkelenz area striking damage building can be found that is caused by uneven heaving. Here, in the sphere of influence of the Roer edge fault system, massive damage on buildings can be found which is related to uneven heaving along the geogenic fault systems. No comparable damage caused by a rise in mine water levels can be documented in the other areas.

Mining Area	Heaving caused by mine water rise	Subsidence caused by mine water rise
Ruhr	up to 20 cm	---
Aachen	up to 30 cm	---
Saar	up to 20 cm	---
Ibbenbueren	up to 10 cm	---
Lugau Oelsnitz	up to 47 mm	up to 40 mm
Doehlen Basin	up to 10 cm	up to 5 cm
Lorrain	10 cm to 20 cm	---
Nord – Pas-de-Calais	---	6 cm
Kempen	3 mm/a to 23 mm/a	4 mm/a to 14 mm/a
Liège	up to 2.5 mm/a	up to 6 mm/a

Table 3 / researched amounts of rising and subsidence of the terrain

5 Recommendations

Exhaustive monitoring has to be done for every rise in mine water levels in order to allow to retrieve data on the status of the mine water and its chemistry at any time.

Potential migration structures have to be clearly assessed regarding both their quality and their quantity. This assessment applies to both the deposit and the overburden and has to consider the structure of old mining, galleries, shafts and drillings, too. Likewise, the tectonic structures and fault systems need to be assessed with regard to their migration potential.

Any changes in the chemical composition of the mine water related to the rise in mine water levels needs to be modelled. If required, appropriate treatment plants have to be planned and erected in due time. Furthermore, the mine water quality also needs to be timely assessed according to the requirements of the European Water Framework Directive.

Although the study does not document any incident where mine or drinking water reservoirs have been impaired, any rise in mine water levels needs to take into account the sustainable protection of natural drinking water reserves. However, the concept of an increased mine water level also needs to consider that the increasing mine water is in fact the natural low groundwater of the deposit as well as inflowing geogenic ground waters for which an overall restoration of a natural water household makes sense. Therefore, exaggerated fears are as inappropriate as worst-case scenarios. Based on technical and matter-of-fact aspects the recommendation has to be to design a sustainable rise of the mine water level for each deposit and to ensure reasonable and sufficient monitoring of those.

Along the sphere of assumed inconsistencies, known large-scale tectonic disruptions and the brims of former mining, a denser network of height benchmarks should be introduced to record any deviations in heaving in due time. Likewise, the mine water rise should be done as evenly and large-scale as possible.

Reference

Melchers, Ch., Doğan, T. (2014): Recherche und Bewertung erfolgter Grubenflutungen in Steinkohlenrevieren Deutschlands und des europäischen Raumes (Research and assessment of occurred mine water flooding in hard-coal mining areas of Germany and Europe). – 30 p., 19 Fig., 4 Tab., 5 App.; Bochum, unpublished expert opinion commissioned by RAG AG.

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