Coal mine flooding in the Lorraine-Saar basin: experience from the French mines

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Abstract

Coal mining in the Lorraine-Saar basin started in the nineteenth century. The coal deposit was mined both in France and in Germany. On the French side, mining ceased in 2004 after 150 years of activity, and as a consequence, the French coal mines got progressively flooded. This study presents the results of the entire monitoring plan for the different mine water reservoirs of the Lorraine coal basin. The actual speed of mine flooding is compared to prediction studies, mine water quality is detailed and content evolution of iron, manganese and suspended solids is discussed for the different mine reservoirs.

Keywords: hard coal, mine flooding, water quality, Lorraine-Saar basin

Introduction

Coal mining in the Lorraine-Saar basin started in the nineteenth century. The last French coal was mined in April 2004, and once mining stopped, the water that was infiltrating from groundwater to underground mine workings was no longer pumped out to the surface by the mine operator, Charbonnages de France (CdF). From 2006, mine workings got progressively flooded, creating mine water reservoirs (Figure 1).

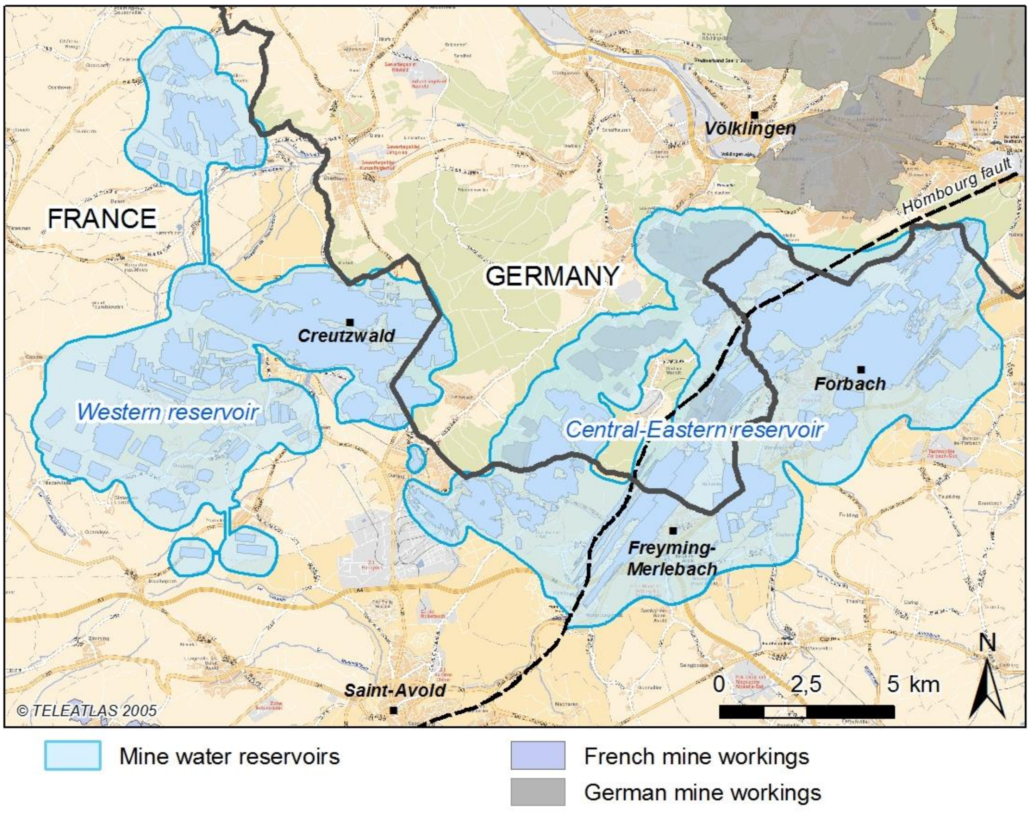

Figure 1 - Mine workings and mine water reservoirs of the Lorraine-Saar basin.

Before its dissolution in 2007, CdF planned and financed remediation operations, including studies to understand mine flooding and its consequences. After the transfer of responsibility for CdF's facilities to the French State in 2008, the Mine Safety and Risk Prevention Department of the French Geological Survey has been managing this remediation activity.

Mine flooding

In 2001, the mine operator CdF started investigating the mechanisms of mine flooding and its consequences. Although coal mines were still operating in the Lorraine basin, planning ahead for post-mining remediation turned out to be necessary.

Mine flooding predictions

Mine flooding assessment was carried out in two phases: volume computation of the residual mining voids and simulation of mine flooding. The first phase started in 2002 and ended in 2005, with a team dedicated only to that task. First, all mine workings maps were digitized, including coal seams and galleries of all exploitation levels for the different exploitation fields. In 2002, CdF used an isolated exploitation field as a case study, to determine coefficient for residual voids depending on the depth of the mine workings and the backfilling methods (Degas 2002). Then from 2003 to 2005, residual mining voids were computed using the residual voids coefficients and the digitized maps, block after block, level after level, for all the mine workings.

The simulation of mine flooding was done in 2006. At that time, CdF was still pumping out water from the underground mine workings. The flow rates of each mine block were assessed and used for the simulation. They were considered equivalent to the flow rates of infiltrating water from the above groundwater. CdF also assessed the state of all galleries linking exploitation fields to each other, concluding that the main galleries were still open. At last, using the residual mining voids, the flow rates of infiltrating water of each block and the connections between each exploitation field, CdF used a simple computation to make mine flooding predictions.

Predictions versus reality

Mine flooding predictions were made for each exploitation field. The example of the Forbach exploitation field, in the Central-Eastern mine water reservoir, is shown on Figure 2. Two mine flooding scenarios were studied by CdF. The first scenario considered that infiltrations would stay constant until all the mine workings would be flooded, up to the semi-permeable geological layer of the Permian. The second scenario considered that the infiltrations would decrease once the mine flooding reached the last hundred meters of the mine workings.

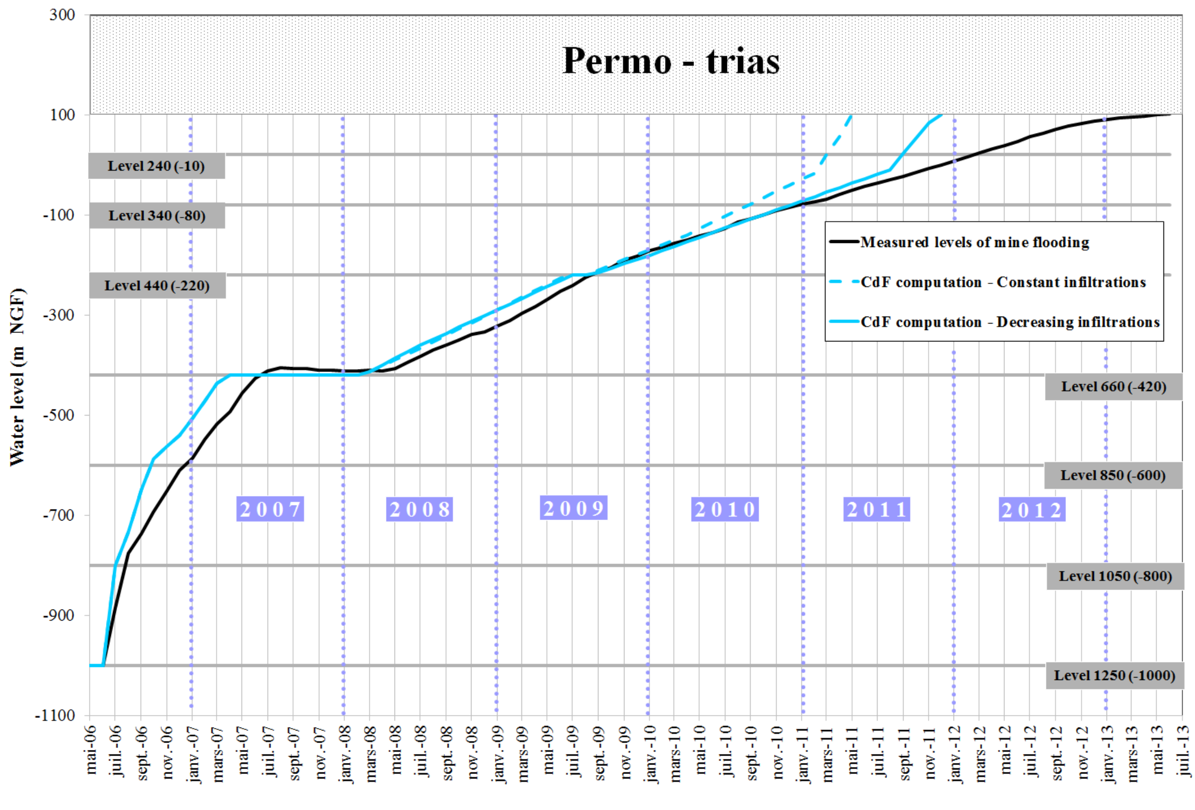

Figure 2 *- Mine flooding of the Forbach exploitation field.*

The mine flooding predictions made all over the Lorraine basin turned out to be pretty accurate. For the Forbach exploitation field, the speed of flooding for the first 500 meters was overestimated by only a month (Figure 2), probably due to a slight inaccuracy of the residual voids coefficient. Out of the two scenarios studied by CdF, the scenario taking into account a decrease in the infiltrations is the most realistic. However, the speed of flooding for the last 150 meters before reaching the Permian layer was also overestimated, by just over a year. As the shallow mine workings date from early 1900's, the residual mining voids were not easy to assess. The inaccuracy of the prediction of the last 150 meters is most probably due to an inaccurate residual voids computation.

Feedback on mine flooding predictions

Although CdF used a straightforward way to predict mine flooding for the coal mines of the Lorraine basin, the predictions were quite accurate. The key of mine flooding predictions turned out to be data gathering, and not sophisticated computations. Only staff members of the mine operator were able to properly assess residual mining voids and the state of the galleries connecting exploitation fields. However, even with the experience, those miners had trouble assessing old mine workings, and as discussed previously, this inaccuracy immediately lead to an overestimation of the speed of mine flooding.

Mine water quality

To prevent mine water from contaminating the above groundwater once the mine water level has reached the Permian layer, three mine water pumping stations associated to treatment schemes have been built on the Lorraine coal basin. Those pumping stations enable to keep mine flooding under control. They are run by the BRGM as part of their post-mining missions.

Mine water quality monitoring

Water sampling and water analysis are run on the three pumping stations. The pumping stations are installed in old mine shafts, with access to the mine workings. When the coal mines closed, some of the underground mining facilities could not be removed. After being emptied and cleaned, some of the facilities stayed in place, including machinery, electrical and hydraulic installations. Despite all the precautions taken, some industrial toxic products such as oils and resins might have remained underground. As a consequence, the water quality is closely monitored, especially regarding dangerous substances. Water analysis for dangerous substances is carried out every three months.

The dangerous substances analysed are the following: ammonium, cyanide, arsenic, cadmium, chromium, copper, nickel, lead, zinc, phenol index, total hydrocarbons, BTEX (4), PAHs (16), formaldehydes, isocyanates, PCBs, halogenated VOCs.

Mine water quality results

The treatment scheme of La Houve is located in Creutzwald, it treats mine water from the Western mine water reservoir. The treatment scheme has been operating since November 2009. In the first two years, cyanide and a few PAHs and BTEX were found in raw mine water at concentrations higher than the environmental quality standards (EQS). Since then, no dangerous substances have been quantified at concentrations higher than the EQS.

The treatment scheme of Simon treats mine water from the Central-Eastern mine water reservoir. The scheme is located in Forbach and has been operating since November 2012. Copper and zinc have been found in raw mine water at concentrations higher than the EQS, since the beginning of pumping. The other substances have not been quantified at concentrations higher than the EQS.

The treatment scheme of Vouters also treats water from the Central-Eastern mine water reservoir, like the treatment scheme of Simon. The scheme is located in Freyming-Merlebach and has been operating since July 2015. Copper and zinc have also been found in raw mine water at concentrations higher than the EQS, since the beginning of pumping. The other substances have not been quantified at concentrations higher than the EQS.

Content evolution of iron and manganese

While pumping stations enable to keep mine flooding under control, treatment schemes enable to lower the raw mine water content in iron, manganese and total suspended solids (TSS), before discharging the treated mine water in local rivers. To design water treatment schemes, predictions of mine water content are essential.

Mine water content predictions

Predictions of iron and manganese evolution in the raw mine water were made using the work of Younger (Younger 2000). Similar hypothesis were used for the different pumping stations and water treatment schemes.

As an example, the main hypotheses for iron evolution were:

- pic concentration of 98 mg/L (± 14 mg/L) and stabilization at 5 mg/L (± 1,25 mg/L)
- kinetics based on a mine water emergence with a constant flow rate
- 10 % of the volume of the mine reservoir to be leached out by water circulation

Predictions versus reality

Iron and manganese evolutions at the pumping station of La Houve are presented Figure 3.

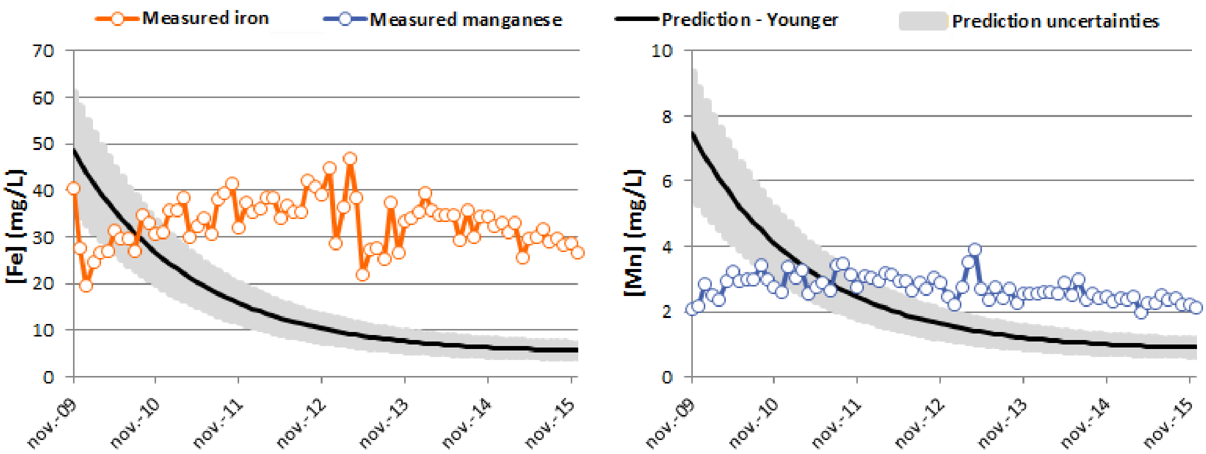

Figure 3 *- Iron and manganese evolution at the pumping station of La Houve.*

The predictions for iron and manganese evolution at the pumping stations turned out to be wrong. Concentrations were supposed to be high at the start of the emergence, but decreasing quite strongly in a short time. Looking at the real data, it appears that the concentrations did not go that high, and then decreased in a much slower way. Such a difference between the predictions and the real data is a major issue, as the predictions were used to design the water treatment schemes.

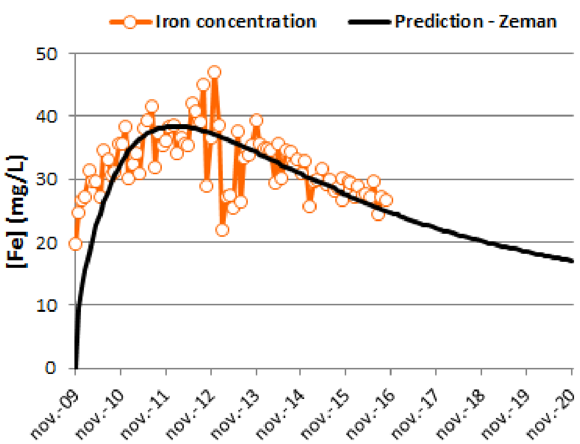

Figure 4 *- Updated iron prediction at the pumping station of La Houve.*

However, predicting iron and manganese evolution is not an easy task. Furthermore, at the time CdF did that study, the pumping stations were not yet an option, and an emergence was supposed to be set up instead. Using the work of Zeman (Zeman 2009), predictions for iron and manganese evolution were updated by the BRGM (**Figure 4**).

While the initial study predicted that raw mine water would reach an iron concentration above 10 mg/L by 2013, the new prediction clearly shows that even in 2020, the iron concentration will not have reached the 10 mg/L threshold.

Mine water content predictions feedback

The main issue with the predictions made using Younger's work was the use of a constant flow rate. Indeed, the mine water pumping stations run at a variable pumping rate that keeps increasing over the years and will reach its maximum at around 2050. As shown in Figure 5, iron concentration tends to increase with the flow rate. Once the flow rate is stabilized, the iron concentration decreases.

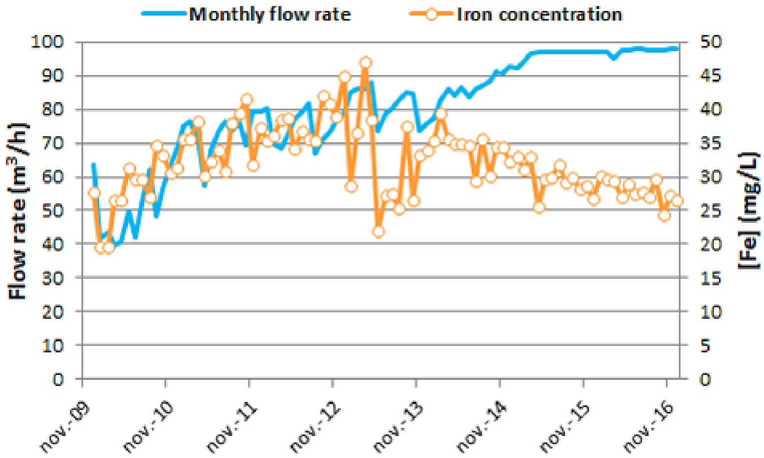

Figure 5 - *Correlation between variations in flow rate and iron concentration at La Houve pumping station.*

Conclusions

Looking at the example of the French coal mine flooding, it appears that for mine flooding predictions, collecting and computing accurate data is the key element to keep in mind. The use of an isolated exploitation field as a case study to determine coefficient for residual voids, has also been decisive for the accuracy of the predictions.

Regarding the water quality of the two mine water reservoirs of the Lorraine basin, only a few toxic substances were quantified above the EQS at the start of the La Houve treatment scheme. Since then, no dangerous substances have been quantified at concentrations higher than the EQS, whether in the Western mine water reservoir, or in the Central-Eastern mine water reservoir.

At last, predicting water quality evolution in terms of iron and manganese is known to be a difficult task. In the Lorraine basin, the predictions did not take into account the evolution of the pumping rates of the pumping stations. As a consequence, the predictions overestimated the pic concentration, and underestimated the time for the concentration to decrease. Such a difference between the predictions and the real data is a major issue, as predictions of water quality are used to design water treatment schemes.

References

Degas M (2002) Bassin houiller de Lorraine. Détermination du volume des vides miniers résiduels - Cas du bassin de Faulquemont. Houillères du Bassin de Lorraine et Deutsche Steinkohle, reference INERIS-DRS-04-46846/R01

Younger PL (2000). Predicting temporal changes in total iron concentrations in groundwaters flowing from abandoned deep mines: a first approximation. Journal of Contaminant Hydrology, 44(1), pp. 47-69.

Zeman J, Černík M, and Šupíková I (2009) - Dynamic model of long term geochemical evolution of mine water after mine closure and flooding. Water Institute of Southern Africa & International Mine Water Association: Proceedings. International Mine Water Conference. Pretoria, pp. 828-836.