

On site feasibility study on biotechnical sulphate reduction

André Gerth¹, Anja Hebner¹, Friedrich-Carl Benthaus²

¹Vita 34 AG, Geschäftsbereich BioPlanta, Deutscher Platz 5a, 04103 Leipzig, Germany
info@vita34.de

²Lausitzer und Mitteldeutsche Bergbau-Verwaltungsgesellschaft mbH, Knappenstraße 1,
01968 Senftenberg, Germany
FC.Benthaus@lmbv.de

Abstract

Reduction of sulphate load in groundwater and surface water are one of lignite mining related tasks in Germany. *On site* investigations on biotechnical sulphate reduction in surface water were realized by Vita 34 on a pilot scale. This test was financed by LMBV, who is in charge of the mining liabilities of lignite mining. Sulphate rich water demands long-lasting treatment to minimize environmental impacts.

At a former lignite mining site near Leipzig (Saxony, Germany), a pilot system for sulphate removal using a fixed bed system was constructed, operated and monitored (Schumann and Hebner 2012). For efficient pollutant removal the following main processes were applied:

- microbial reduction of sulphate to sulfide ions
- oxidation of iron to ferrous iron
- reaction of sulfid ions with ferrous iron and precipitation of iron sulphide.

Sulphate rich surface water from a nearby channel (fig. 1) was pumped into the pilot system consisting of three treatment stages. Most important advantages of this technology are: subsurface installation of a fixed bed, no treatment residues are generated, low demand on energy and technical equipment.



Figure 1 Ariel view of former lignite mining site in Saxony (Source: LMBV)

Beside the pH-value, TOC, TIC, sulphate, sulfide and iron content, calcium concentration and acid capacity were monitored during six months at several monitoring points along the treatment chain.

The sulphate content of about 1,120 mg/L was reduced to <300 mg/L (target value) in surface water. During pilot investigations a maximum sulphate reduction rate of about 6.7 mol/(m³*d) respectively

3 mol/d was achieved. Figure 1 shows cumulated sulphate load in the inlet and outlet of the pilot system during operation.

Besides, dependency of sulphate reduction rate on temperature, carbon and sulphate availability, changes in pH-value and content of dissolved iron were verified.

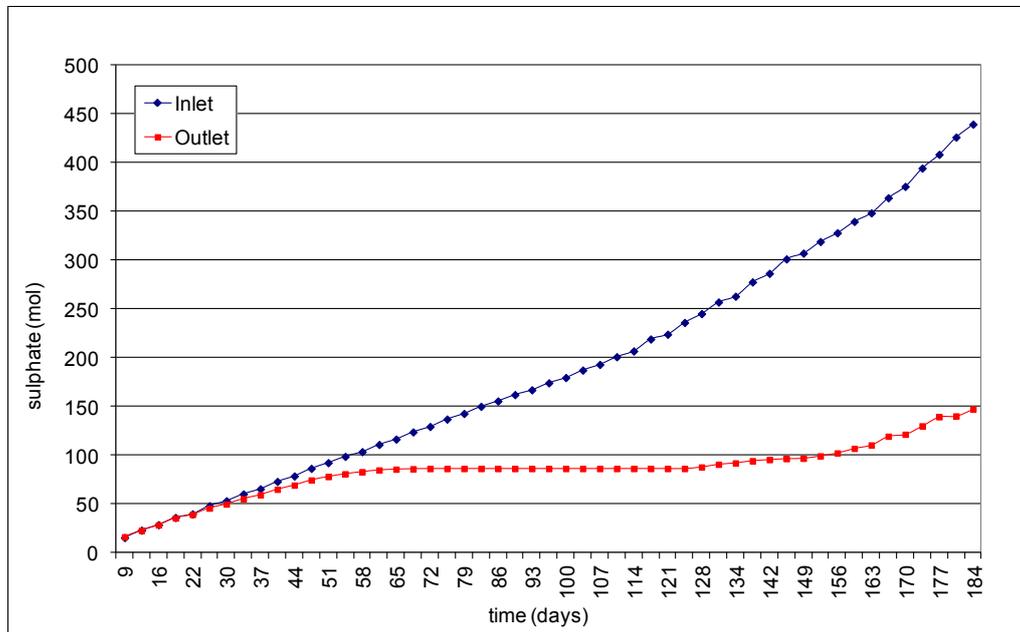


Figure 2 cumulative sulphate amount in inlet and outlet of pilot system [1]

Key words: sulphate, water, treatment, microbial sulphate reduction, on site, in situ, feasibility study

Introduction

At many German lignite coal mining areas sulphate containing water derives as well as sites are related to impacts on groundwater.

Lots of investigations were developed focusing management options for sulphate rich surface and groundwater.

In Saxony and Brandenburg several open mine pits were or will be recultivated. Recultivation measures are associated in many cases with procedures on water treatment.

Vita 34 together with LMBV has developed an *on site* pilot trial at a lignite coal mining area situated in southern part of Saxony (Germany).

The treatment concept is based on earlier R&D-investigations on microbial sulphate reduction which were developed on a small and a technical scale.

The concept for treatment of sulphate rich water incorporates needed processes for pollutant removal using following stages (fig. 3):

- 1) oxygen depletion within a retaining basin with addition of a liquid carbon and nitrogen source,
- 2) sulphate reduction and sulfide immobilization within a sealed system with a fixed bed made from gravel with addition of granular iron,
- 3) carbon degradation within a planted gravel filter.

The last stage is needed because an organic carbon source has to be added to catalyse microbial sulphate transformation. Sulphate is transformed to sulphide which reacts with ferrous iron and precipitates as iron sulphide.

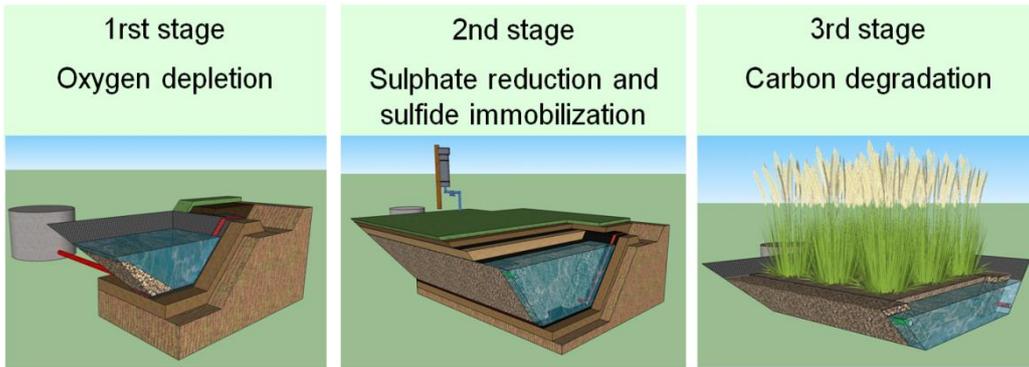


Figure 3 3D-illustration on treatment stages

Methodology

For *on site* investigation a pilot system was installed, operated and monitored for about six months. Sulphate rich surface water was taken from a channel which dewateres a flooded open mine pit to river Pleiße (fig. 4).

Sulphate concentration in water is about 1,120 mg/L and pH-value between 4 and 7. Dimension and operation parameter of the pilot plant are listed in table 1.

During continuous operation and monitoring of the pilot plant the flow rate and added amount of carbon source was increased several times.



Figure 4 Pilot plant at former lignite mining site

Table 1 main design and operation parameter

	stage 1	stage 2	stage 3
volumetric capacity	0.5 m ³	3.8 m ³	1.3 m ³
pore volume	0.5 m ³	ca. 1 m ³	0.4 m ³
retention time (min.)	0.5 d	2.5 d	0.7 d
flow distance	-	18 m	2.5 m

Results and discussion

At least 20 days after the start of operation microbial sulphate reduction became effective (fig. 4) and after additional 40 days the sulphate concentration fell below target value.

As stable conditions were accomplished the flow rate was increased step by step and the amount of organic carbon source was optimized. Figure 5 illustrates monitored sulphate concentration in effluent of the overall system corresponding to air temperature.

Lab results of samples which were taken at several sampling points of second treatment stages proofed an efficient sulphate removal. Sulphate concentration was partly after 6 m of in total 18 m flow distance below target or detection limit.

Microbial sulphate reduction was partly limited by insufficient sulphate supply given by combination of chosen flow rate, retention time and sulphate content in surface water, which had to be treated previously.

Oxidation of iron followed by precipitation of iron sulfide was suitable to prevent measurable concentrations of sulfide in the effluent. At the beginning of the pilot operation high amounts of ferrous iron in the effluent had to be managed. During the pilot operation a temporary sedimentation stage was needed to prevent discharge of iron to the environment.

By the end of monitoring of the pilot plant scheduled changes in operation as well as a decrease of air temperature in autumn led to declining treatment efficiency.

Additionally oxidative release of ferrous iron seemed to decline. This was caused by inerting of surface of iron granulate.

A mass balance for iron, sulfur and calcium in the fixed bed was conducted. Based on these results, the amount of generated precipitates was estimated (Schöpke and Preuss 2012). After six months of pilot operation investigated characteristics of fixed bed material, as well as results of mass balances, indicated no significant changes of hydraulic conditions caused by precipitates.

Altogether retention time could be decreased from 7 to 4 days by more or less constant efficiency. This led to an optimization of dimension and investment costs for targeted full-scale application.

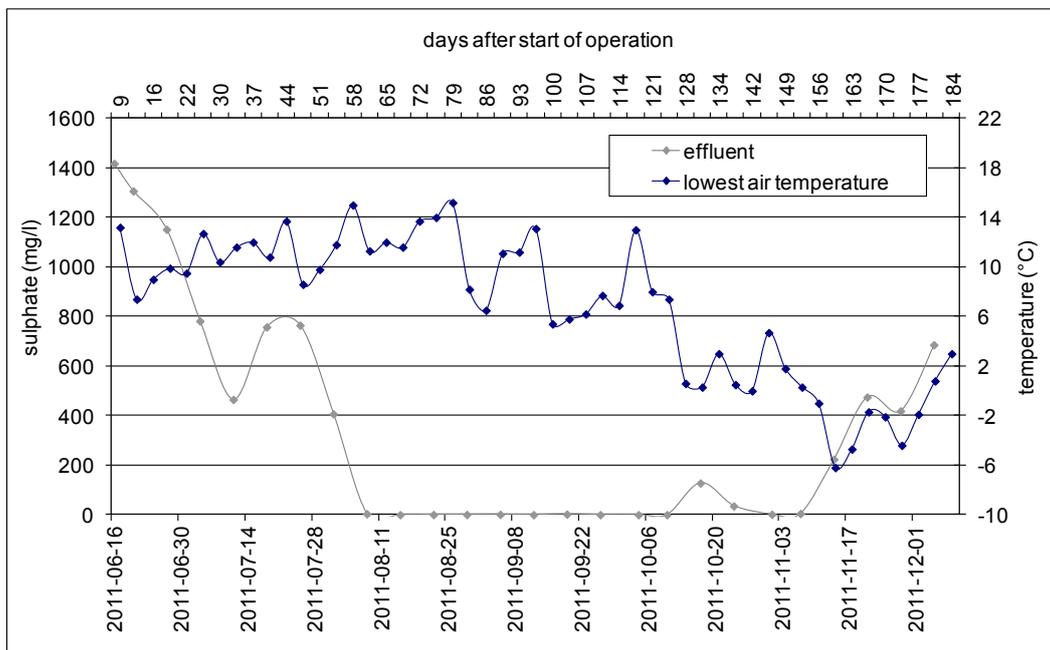


Figure 5 Monitoring results – sulphate concentration versus time

Conclusions

Numerous coal mine pits in Germany were flooded by re-rise of groundwater level after mine closure or controlled feeding using surface water of nearby rivers. The water quality of created lakes is influenced by interactions with sulphate containing groundwater.

Vita 34 has realized a six months *on site* water treatment pilot test on sulphate reduction and sulphide immobilisation in a biological active filter. Average sulphate concentration of about 1,120 mg/L decreased below target value of 300 mg/L. In the *on site* pilot test even a higher sulphate reduction rate could be obtained than in own previous investigations on a technical scale.

Changes in release of ferrous iron as well as influence of air temperature during winter periods need to be managed to ensure compliance with regulations.

The decrease of rate of oxidation of iron to ferrous iron can be compensated by subsequent delivery of iron granulate. The impact of low temperatures on treatment efficiency can be decreased by construction of stages below ground level. Additionally, temperature-dependent sulphate transformation kinetics has to be considered during the design of treatment plants for full-scale application.

Innovative technical approaches which allows selective replacement of parts of the fixed bed makes this technology favorable for full-scale and long term application *on site* as well as *in situ*.

During operation no residues have to be managed. Reaction products and by-products were immobilized and remain as solids in the treatment plants. In case fixed bed has to be replaced or when treatment plants are taken out of operation then sustainable and secure re-utilization of the fixed bed material is required. Special attention has to be paid to the professional utilization because it is charged with iron sulphide. One strategy is to depose material in anoxic conditions in underground.

Acknowledgements

Described pilot investigations were undertaken by Vita 34 (business unit BioPlanta) on behalf of Lausitzer und Mitteldeutsche Bergbau-Verwaltungsgesellschaft. As external consultants Dresdner Grundwasserforschungszentrum e.V. and Institut für Wasserwirtschaft, Siedlungswasserbau und Ökologie (IWSÖ) GmbH were involved.

References

- Schumann, A.; Hebner, A. (2012) *On site* Versuch zur technischen Anwendung biologischer Sulfatreduktionsprozesse - Abschlussbericht
- Schöpke, R.; Preuß, R. (2012) Zuarbeit zur Auswertung des Pilot- und Demonstrations-Versuchs zur Sulfatreduktion am Hainer See