Experiences in neutralising acidic pit lakes by flooding with river water

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Abstract

Pit lakes are the result of large surface mining with deep lowering of the water table. After cessation of mining and stopping of dewatering, often the rising lakes are acidified by pyrite oxidation. The flooding of such lakes with neutral river water is one possibility to abate acidification. In addition the fast flooding of pits with river water results in a stabilisation of the side walls of the pits.

In the lignite mining districts in the eastern part of Germany the flooding with river water is the preferred way of remediation. The risks are the mobilisation of acidity by erosion and land slides and the eutrophication of the created lakes by the high phosphorus content of the river water.

A detailed study of the flooding of the mining lake Goitsche near Bitterfeld (Central German lignite mining district) confirmed the important influence of erosion and of lake stratification on the progress and success of neutralisation. In addition the results indicated that phosphorus from flooding water is removed by precipitation with iron and aluminium during neutralisation. The long term behaviour of the phosphorus in the sediment is subject of ongoing research.

1 Introduction

Artificial lakes are one of the most prominent residual features of lignite surface mining. In many cases, the diversion of river water is considered to reduce the filling time of the pits, to stabilise the sidewalls, and to abate acidification of new pit lakes. Acidification and eutrophication are the most important aspects of water quality in pit lakes filled with river water (Klapper & Schultze 1995). For most favourable flooding operations, a good knowledge of all relevant processes is required. Interactions between water and sediment, precipitation and microbiologically mediated reactions affect the formation of lake water quality during flooding, in addition to mixing of flooding water with water of precursor lakes and inflowing ground water (figure 1).

To get a deeper quantitative insight into the flooding process with all relevant factors the flooding of the former opencast mine Goitsche near Bitterfeld (Germany) with water from the river Mulde was studied in detail during its filling from May 1999 to April 2002. This paper is focused on parameters reflecting acidification and eutrophication: pH, alkalinity, sulfate and phosphorus.

2 Study site

The former lignite mine Goitsche is situated immediately south-east of Bitterfeld in the Central German mining district (figure 2). As a result of the mining progress the residual mining lake is subdivided in three basins called Mühlbeck, Niemegk and Döbern. After closing the mine (in 1991) small precursor lakes had been formed by rising ground water. The surfaces of these lakes were stabilised by pumping excessive water to river Mulde at different levels (see figure 3). Because of high concentrations of pyrite and its oxidation during the dewatering of the underground along the mining process the precursor lakes in the basins Mühlbeck and Niemegk were acidified. As a result of the differing local geological conditions the precursor lake in basin Döbern was neutral (figure 4, Kringel et al. 2000, Grützmacher et al. 2001).

The flooding of the mine with water from river Mulde started in May 1999 and stopped in March 2002 at a water level of 71.5 m a.s.l. At this time Lake Goitsche had a volume of 166×10^6 m^3 and a surface area of 10.5×10^6 m^2. The maximum depth was 42 m, the average depth 15.8 m.

3 Results and discussion

During flooding a chemical differentiation occurred between epilimnion and hypolimnion in addition to the thermal stratification (Kuehn et al. 2001, Schultze et al. 2002). This chemical differentiation stabilised the stratification and resulted from the different densities of the lake water and the flooding water. As a consequence, during the stratification period the flooding water mixed only with the epilimnion and only the epilimnion was neutralised. The development of pH is displayed in figure 4 for surface water and water from lake bottom for all basins of Lake Goitsche.

To get a measure for the total amount of acidity and alkalinity, the stocks of alkalinity of the separate basins and the total input of alkalinity of introduced river water were calculated. The results presented in figure 5 confirm the increase of acidity by erosion and elution of soils containing acid during summer 1999 in basin Niemegk. In addition, Figure 5 confirms the fast decrease of acidity in winter 1999/2000. The decrease of acidity between summer 1999 and spring 2000 in basin Niemegk surpassed the cumulated import of alkalinity with river water. This effect was caused by landslides at the slopes of the pit and consequent slumping of soil containing carbonates. Obviously, erosion and elution of carbonate containing soils by rain and waves also contributed to the neutralisation progress.

The influence of erosion and elution on the water quality in the lake is also reflected by the changes of stocks of sulfate in the lake (figure 6). The river water contributed 32% of the final amount of sulphate in the lake. 18% of the final stock of sulphate in the lake originated from the precursor lakes. That means 50% of the sulphate in the lake were introduced during the flooding by erosion, elution and inflow of ground water.

Figure 7 presents the changes of stocks of phosphorus in the lake water along the flooding. In contrast to the results for sulfate the final stock of phosphorus in the lake is much smaller than the amount of phosphorus imported with the river water. Only about 8% of the phosphorus of the flooding water was still present in the lake water in spring 2002. All the rest including the stocks of phosphorus of the precursor lakes was removed from lake water and bound in the sediment. As the acidic mine water enriched in Fe, Al, and sulfate mixes with neutral river water, chemically active Fe- and Al-(hydroxy)oxides and -sulfates precipitate and sorb phosphorus from the water. The fact that the nearly complete precipitation of phosphorus went on after neutralisation in 2001 was a surprising result of our investigations. Incorporation of phosphorus into planktonic biomass and subsequent settling of dead plankton organisms seem to be the main mechanism of phosphorus removal after neutralisation. Chemical investigations of the settling material and the sediments indicated that the majority of the phosphorus is bond to iron (Schultze et al. 2002, Duffek & Langner, 2003). This includes the possibility of re-dissolution of the phosphorus from the sediment as a result of reductive processes in the sediment in the future.

4 Conclusions

The former opencast mine Goitsche were neutralised successfully by flooding with river water. The erosion and elution of natural deposits of carbonate containing soils also contributed to the neutralisation progress. The neutralisation was complete by March 2001, when the lake had reached about 64% of its final volume.

The chemical evolution in the lake water was strongly influenced by dilution in connection with secondary in-lake processes like precipitation and sorption. Despite of the initially high concentration of phosphorus in the river water (approx. 0.1 mg/L), eutrophication of the lake could not establish, since the phosphorus concentration in the lake remained remarkable below the concentration of the flooding water.

The results indicate the filling of pit lakes with river water as a viable way to achieve good water quality. The detailed study of the processes during the flooding offers the opportunity for future improving the modelling and prediction of water quality in flooded mining lakes.

5 Acknowledgement

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6 References

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7 Figures

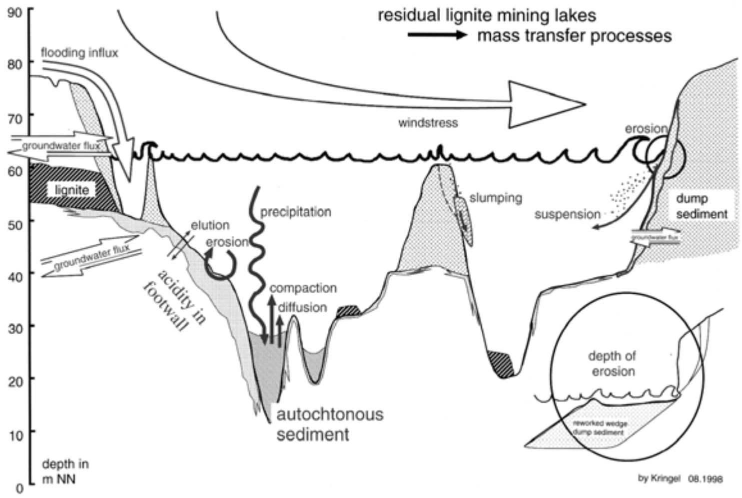

Figure 1 Various factors relevant for the mass flow of acidity and alkalinity in the flooding process of an acidic mining lake (after Kringel et al. 2000)

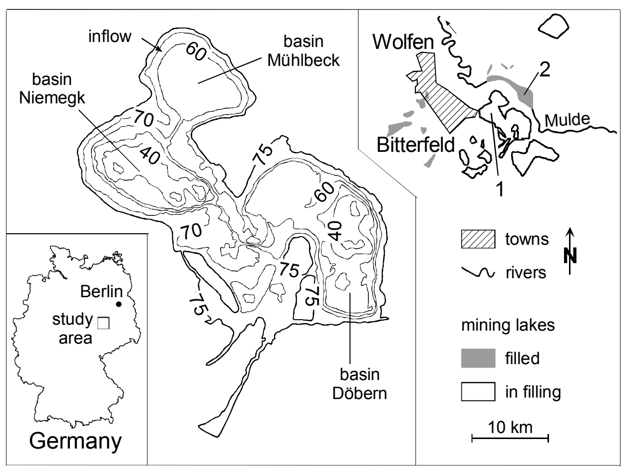

Figure 2 Map of mining lake Goitsche (numbers in the central panel: m above sea level; numbers in the right panel: 1 – mining lake Goitsche, 2 – Mulde reservoir)

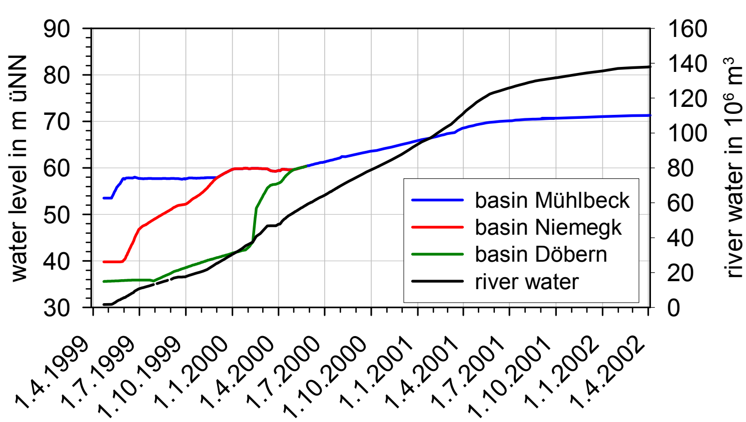

Figure 3 Evolution of the water level in the basins of Lake Goitsche and amount of introduced river water

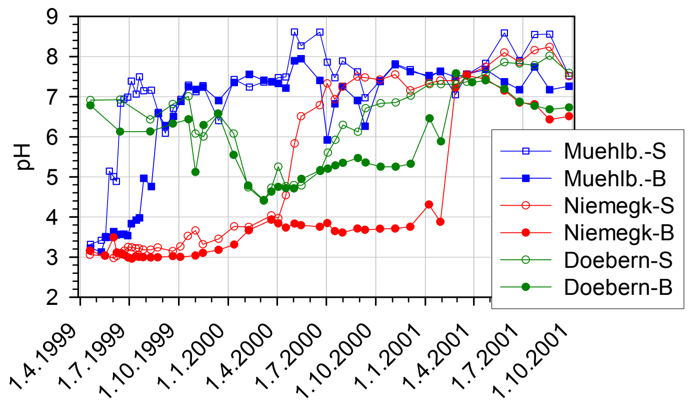

Figure 4 Development of pH in the basins of Lake Goitsche from 1999 to 2002 (S means lake surface, B means lake bottom)

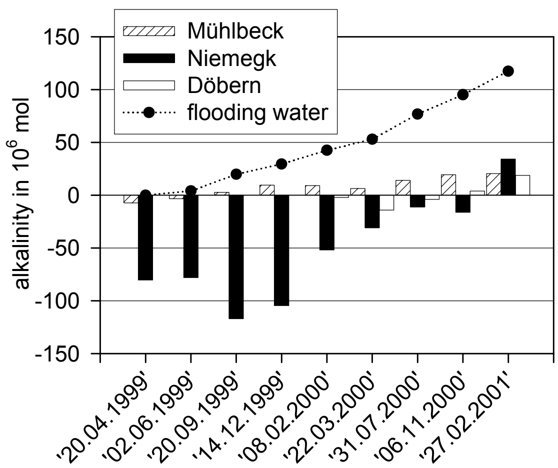

Figure 5 Stocks of alkalinity in Lake Goitsche at selected dates during flooding, including total input of alkalinity from river water. Negative values indicate remaining stocks of acidity.

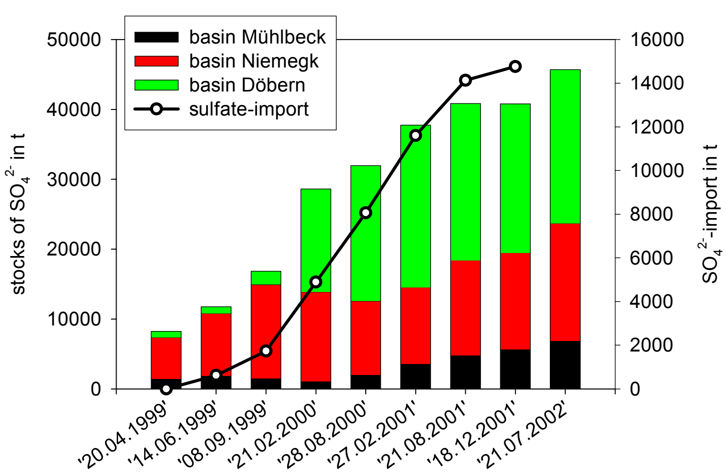

Figure 6 Stocks of sulfate in Lake Goitsche at selected dates during flooding, including total import of sulfate with river water

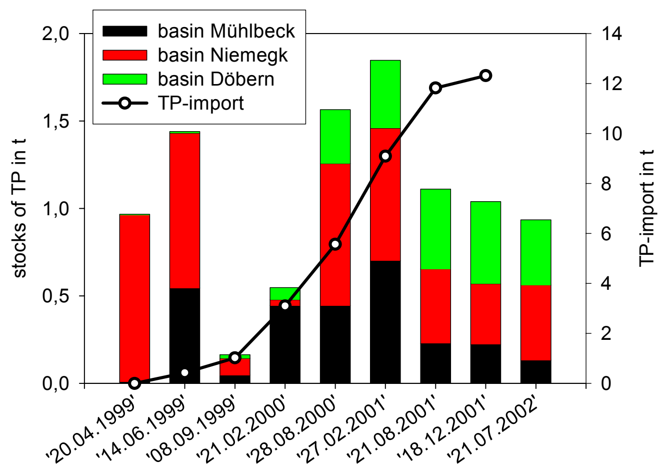

Figure 7 Stocks of total phosphorus (TP) in Lake Goitsche at selected dates during flooding, including total import of phosphorus with river water