Investigating the Effects of Storm Events on the Temporal Dynamics of Acid Mine Drainage Loads in Receiving Streams of the Lusatian Lignite Mining District (Germany)

Extended Abstract for Poster Presentation

Erik Nixdorf[1,2], Maik Boehmeke[1], Marcus Fahle[1]

[1]*Federal Institute for Geosciences and Natural Resources, Cottbus, Germany, 2Helmholtz-Centre for Environmental Research UFZ, Leipzig, Germany*

Keywords: Lignite mining, acid mine drainage, surface water quality, event-driven monitoring

For more than 100 years, opencast lignite mining in the Lusatian Mining District has transformed more than 800 km² of landscape in East Germany, forming a distinctive pattern of active mines, post-mining lakes, reclaimed agricultural land and forests (Krümmelbein *et al.* 2012). Dewatering, aeration, and rewetting of iron sulfide containing sediments during the mining cycle led to the formation of strong acid mine drainage (AMD) loads. The AMD pollution of the River Spree, which drains the central part of the mining district, mainly originates from an area in the southern part of the mining district, the Spreewitz glacial channel (Fig. 1, left). Extensive AMD management and remediation measures are required to reduce the negative influence on the water quality of the Spree River (Pflug 1998).

Water quality can be strongly impacted by storm events due to event-driven dilution or enrichment patterns in the catchment, which overlay seasonal and long-term trends (Musolff *et al.* 2021; Knapp and Musolff 2024). In former mining areas, it has been shown that storm events can increase pollutant loads, including potentially toxic metals, iron, and sulfide by orders of magnitude, highlighting the critical role of flood events in accurately estimating the annual dissolved pollutant load in surface waters (e.g. Blake *et al.* 2003; Cánovas *et al.* 2008; Mayes *et al.* 2021).

In this context, we investigate the temporal dynamics of AMD loads by deploying high-frequency LTC (Level-Temperature-Conductivity) data loggers of type Solinst Levelogger 5 LTC at the Spree River and its tributaries along a 15 km long river section, the Spreewitz glacial channel (Fig. 1, left). Loggers were placed on the streambed in proximity to gauges using concrete slabs (Fig. 1, right).

Data was monitored at a resolution of 10 minutes covering an observation period between April, 10th 2024 and January, 10th 2025 (Fig. 2). In addition, surface water samples at each deployment location have been taken bimonthly. Samples for cation analysis were filtered through 0.45 μm teflon filters, acidified with suprapure nitric acid to a pH <2 and refrigerated until analysis in the laboratory.

Due to the predominance of sulfate as the most relevant electro-active species in the AMD-impacted water of the Spree River and its conservative behaviour, electric conductance measured by each datalogger at high frequency serves as a very good proxy for sulfate concentration. According to the data of our samples, we found a linear correlation of $R^2 = 0.97$ (Fig. 3, left). Hence, we set up a mass balance model for the section of the Spree River between Sprey and Spreewitz by interpreting the

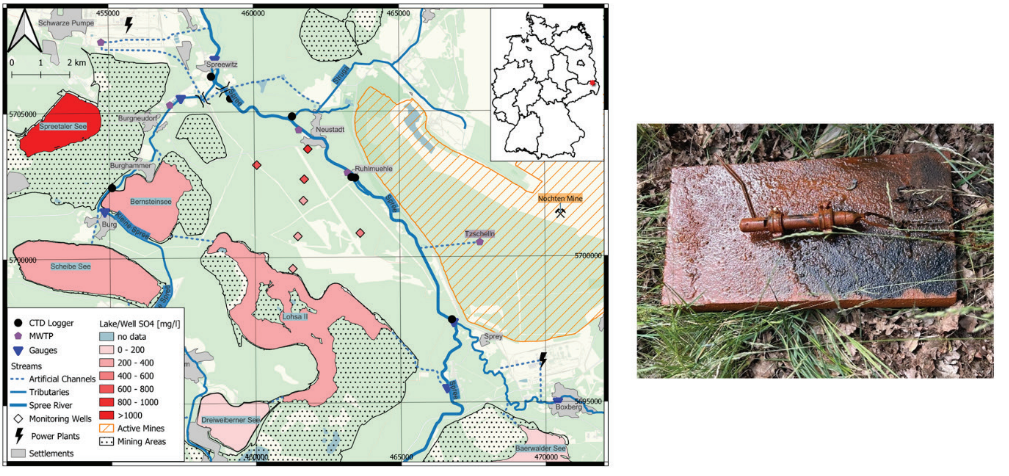

Figure 1 *Left: Map of the study site with relevant installations. Water quality of groundwater wells and mining lakes is provided by (LMBV 2024; Uhlmann et al. 2024). Right: LTC logger anchored on a concrete slab taken out of the water at location Spreewitz. The reddish color is caused by iron hydroxide deposits.*

product of measured flow rate provided by gauging stations and corresponding EC as the electroactive load. This parameter, representing the total load of electroactive species in the water, serves as a proxy for estimating AMD loads entering the stream.

The results indicate that exchange fluxes and their directions vary both spatially and temporally, resulting in a net loss of stream water to the groundwater but a net gain of AMD loads (Fig. 2, lower plot). Analysis of nine major storm events revealed an average increase of approximately 75% in AMD loads entering the stream compared to pre-event conditions, potentially driven by the mobilization of pre-event water stored in sediments. Peaks in AMD loads occurred, on average, 5.6 ± 7.4 hours before the peak discharge, while excess AMD loads ceased 5.2 ± 7.0 hours after the peak discharge. As the events progressed, AMD loads fell below pre-event conditions due to the dilution by stormwater inflow becoming the dominant factor (Fig. 3, right).

Our findings highlight the importance of high-frequency measurements to accurately

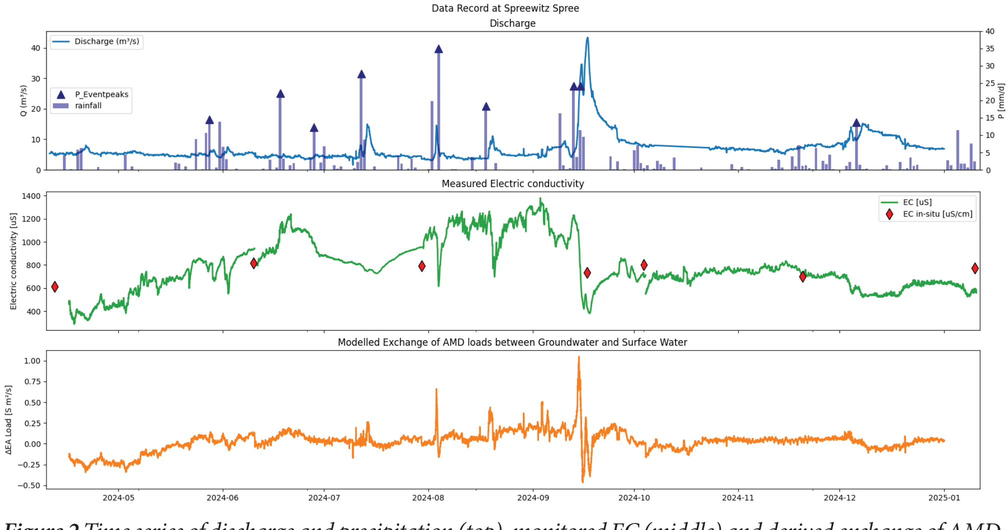

Figure 2 *Time series of discharge and precipitation (top), monitored EC (middle) and derived exchange of AMD loads between surface and groundwater (bottom) in the Spree River at the community Spreewitz.*

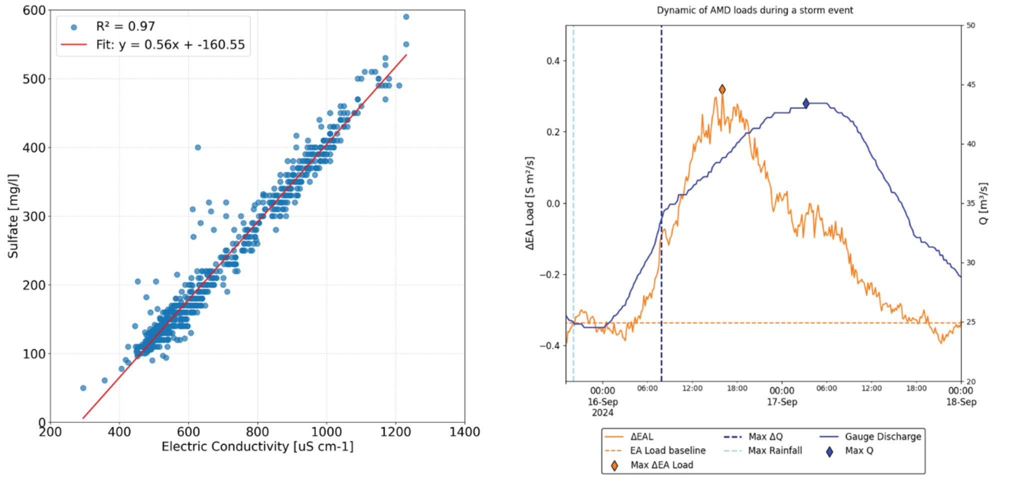

Figure 3 *Left: Correlation between sulfate and EC in the Spree River at the investigation site (586 samples over 30 years at three locations, provided by the local water authorities). Right: Dynamics of exchange of AMD loads between surface and groundwater in the investigated river section during a one in ten years flood event observed in September 2024.*

account AMD loads. They may contribute to enhance AMD load management in receiving waters by adopting measures to reduce peak loads during storm events. Possible measures like optimizing drainage designs and implementing sediment control practices may save costs and improve water quality in surface water bodies affected by acid mine drainage. In addition, accurately accounting outflows of event-induced AMD loads from tailings can improve estimates of remaining AMD stocks in the tailings, allowing for a more precise forecast of the remaining timeframe required for remediation efforts in the receiving waters until pollutant levels drop below environmental standards.

References

Blake WH, Walsh RPD, Barnsley MJ, *et al* (2003) Heavy metal concentrations during storm events in a rehabilitated industrialized catchment. Hydrological Processes 17:1923–1939. https://doi.org/10.1002/hyp.1218

Cánovas CR, Hubbard CG, Olías M, *et al* (2008) Hydrochemical variations and contaminant load in the Río Tinto (Spain) during flood events. Journal of Hydrology 350:25–40. https://doi.org/10.1016/j.jhydrol.2007.11.022

Knapp JLA, Musolff A (2024) Concentration-Discharge Relationships Revisited: Overused But Underutilised? Hydrological Processes 38:e15328. https://doi.org/10.1002/hyp.15328

Krümmelbein J, Bens O, Raab T, Anne Naeth M (2012) A history of lignite coal mining and reclamation practices in Lusatia, eastern Germany. Canadian Journal of Soil Science 92:53–66

LMBV (2024) Wasserwirtschaftlicher Jahresbericht der LMBV mbH 2023. Lausitzer und Mitteldeutsche Bergbau-Verwaltungsgesellschaft mbH, Senftenberg

Mayes WM, Perks MT, Large ARG, *et al* (2021) Effect of an extreme flood event on solute transport and resilience of a mine water treatment system in a mineralised catchment. Science of The Total Environment 750:141693. https://doi.org/10.1016/j.scitotenv.2020.141693

Musolff A, Zhan Q, Dupas R, *et al* (2021) Spatial and Temporal Variability in Concentration-Discharge Relationships at the Event Scale. Water Resources Research 57:e2020WR029442. https://doi.org/10.1029/2020WR029442

Pflug W (1998) Braunkohlentagebau und Rekultivierung: Landschaftsökologie–Folgenutzung–Naturschutz. Springer

Uhlmann W, Hiekel, Robert, Giering, Niklas (2024) Quellenmonitoring und Grundwassermonitoring im Südraum – Hydrologisches Jahr 2023. Institut für Wasser und Boden, Dresden