Ensuring the water quality of post-mining lakes in Central Germany by implementing two different aftercare strategies to meet alkalinity demand

Benno Janisch

benno.janisch@lmbv.de, Lausitzer und Mitteldeutsche Bergbau-Verwaltungsgesellschaft mbH, Leipzig, Germany

Abstract

There are two different aftercare strategies implemented by the Lausitzer und Mitteldeutsche Bergbau-Verwaltungsgesellschaft (LMBV) to prevent ongoing acidification of post-mining lakes in Central Germany: the discharge of alkaline river water, if applicable (Lake Zwenkau) and location-independent ship-based liming (Lake Hain and Lake Störmthal). This paper will present and evaluate the results assessing 5 consecutive years of aftercare since 2019 and will give an outlook based on the gained experiences. Relying on the hydrological mining monitoring system, water treatment is realized to guarantee the water bodies' pH-value at ecologically compatible level even while demand fluctuates.

Keywords: Acidification, alkalinity, post-mining lake, liming, neutralisation, pit lake

Introduction

After German Reunification in 1990, the LMBV is responsible for decommissioning and rehabilitation of no longer profitable open-cast lignite mines of Eastern Germany (Schlenstedt 2020). This includes flooding and aftercare of the resulting post-mining lakes in Central Germany, most notably Lake Zwenkau, Lake Hain and Lake Störmthal. One of the first steps was to build a flooding pipeline connecting the still active open-pit mines to the open-pits requiring filling.

After decommissioning of the LMBV flooding pipeline at the end of 2018, used in the later years primarily for aftercare purposes since the former open-pit mines were filled with water, the LMBV needed to use alternative aftercare strategies to ensure the water quality of the post-mining lakes. At Lake Zwenkau inflow of alkaline river water from the Weiße Elster river was available. Therefore, aftercare of the water body´s quality could be realized primarily by using this alkaline river water. If necessary, ship-based liming is also an additional option available on short notice. Lake Hain and Lake Störmthal do not feature any noteworthy inlets of external surface water, leaving limestone treatment by ship as the only feasibly option for aftercare treatment purposes. Without aftercare treatment, due to oxidization of iron-sulfate-minerals (pyrite) in corresponding dumps, the pH values would decrease and cause high iron and aluminium concentrations in the groundwater and ultimately in the lake water. According to the post-mining lake´s legal plan approval decisions (PAD), for environmental reasons the lakes and their discharges are required to have a pH value between 6.0 and 8.0

Methods

After decommissioning of the flooding pipeline in 2018, two basic aftercare strategies are applied to guarantee the water quality of the three post mining lakes:

(1) Use of alkaline external surface water

For Lake Zwenkau, river water from the Weiße Elster River can primarily be used to guarantee the water quality. The alkalinity of the Weiße Elster water varies depending on the runoff between 1.4 mmol/L at high and 2.8 mmol/L at low runoff rates. The Weiße Elster River has a mean discharge of around 16.5 m^3/s at the stream gauge Kleindalzig. Above a runoff of 7 m^3/s, the LMBV is allowed to withdraw 0.5 m^3/s from the river for aftercare purposes of Lake Zwenkau. Depending on the availability of sufficient runoff to allow withdrawal of river water, meeting the alkalinity demand of Lake Zwenkau cannot be guaranteed. Therefore, if the necessary amount of river water for aftercare purposes is not available, an alternative strategy is required at Lake Zwenkau.

(2) Ship-based liming

For the post-mining Lakes Hain and Störmthal, the LMBV can only use ship-based liming due to the absence of any noteworthy receiving waters. The liming campaigns take place discontinuously, (preferentially during full circulation) according to the quality of the water bodies. A hydrological mining monitoring system is in place, providing regular data of water quality, most importantly values of both pH and alkalinity, allowing for estimation of demand for water treatment. The lime (ground $CaCO_3$, either chalk or limestone) is delivered on site by silo vehicles. Either on the lake or in special mixing containers, a 2–5% lime suspension is created using lake water. The suspension is then applied below the water surface (Fig. 1). Depending on the size of lake and treatment duration, smaller or larger push boats or barges are used. In order to increase the yield of alkalinity (efficiency of lime dissolution) the lime suspension is applied at pH values as low as possible. Typically pH values of the water bodies range between 5.5 and 6.0 when lime application is started. According to Totsche et al. (2018) different neutralizing agents are available and used by the LMBV for neutralization purposes. They all have different specific prices per mole of alkalinity and thereby cost-efficiency. However, all three lakes feature a developed ecology and fish population. This is the main reason for the lakes´ PAD demanding an abidance of pH-values between 6 and 8 (temporary lower deviations are accepted just before beginning of liming campaigns). Furthermore, ecological reasons prevent the use of neutralization agents that might cause either over neutralization – such as calcium hydroxide ($Ca(OH)_2$) – or increase salinity of the water bodies – such as soda (Na_2CO_3).

Results

Since 2019 – after decommissioning of the LMBV flooding pipeline at the end of 2018 – alkalinity demand of Lake Hain, Lake Störmthal and Lake Zwenkau is met by either
(1) Use of alkaline external surface water or
(2) Ship-based liming
At Lake Zwenkau, in consecutive 5 years alkalinity demand was covered by aftercare strategy (1) using river water from the Weiße

Figure 1 *Application of lime suspension at lake Störmthal (image: Falk Bräuer, LMBV)*

Elster River. As shown in Fig. 2, during 2019 almost 11 million m³ of river water were available for withdrawal, resulting in around 17.4 million mol_{Alk} input in Lake Zwenkau. Estimated alkalinity demand for this year was 31 million mol/a, resulting in decreasing pH-value from >7 to around 6.3 while also diminishing acid buffer capacity from 0.3 mol/m³ to 0.23 mol/m³. High availability of river water at the beginning of 2020 caused a reversal of pH-value and buffer capacity, averting the need to use of aftercare strategy (2) ship-based liming. Naturally, inflow and outflow of water will cause the water level to rise or fall, resulting in strongly fluctuating water level.

At Lake Hain and Lake Störmthal only Ship-based liming (2) is available as aftercare strategy to meet alkalinity demand. Table 1 and Table 2 give an overview of estimated annual alkalinity demand based on limnological predictions as well as actual demand for Lake Hain and Lain Störmthal between 2019 and 2023 according to subsequent calculations

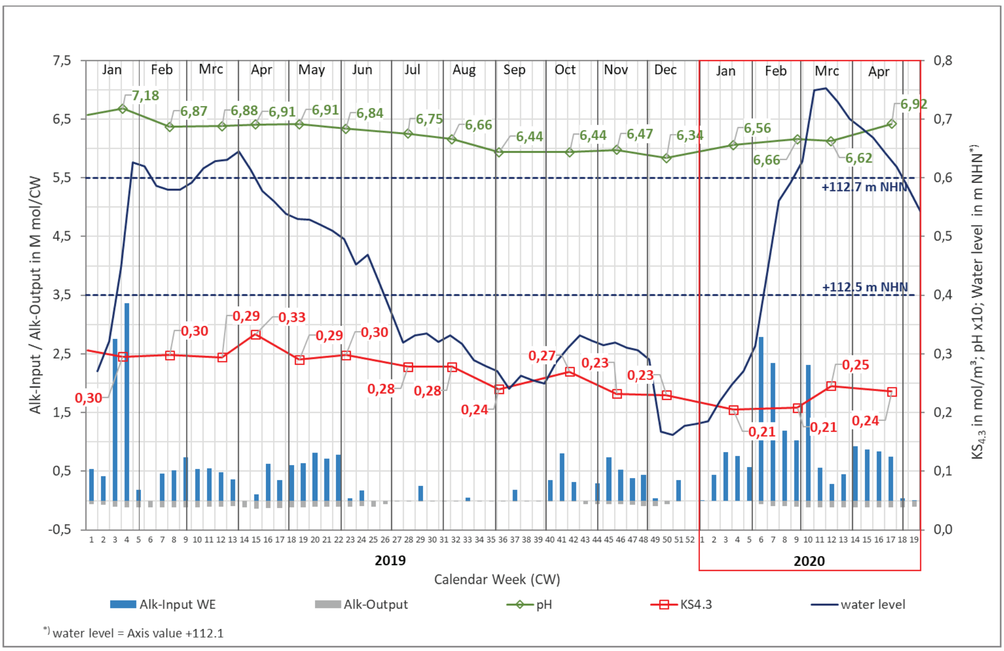

Figure 2 *Overview of monitoring data (pH, $KS_{4.3}$, water level) and alkalinity input and output at Lake Zwenkau throughout 2019 and part of 2020*

Table 1 *Overview of limestone input at Lake Hain 2019 – 2023*

Lake Hain	Input limestone [t]	≈ Input alkalinity [Mmol]
estimated annual demand	*1,000**	*12**
2019	1,003	14.042
2020	500	7
2021	798	11.172
2022	0	0
2023	604	8.456
Total 2019–2023	**2,905**	**40.67**

* conservatively estimated average neutralization equivalent of 12 $mol_{Alk}/kg_{limestone}$

***Table 2** Overview of limestone input at Lake Störmthal 2019 - 2023*

Lake Störmthal	**Input limestone [t]**	**≈ Input alkalinity [M mol]**
estimated annual demand	*1,750**	*22**
2019-1	1,948	27.272
2019-2	1,046	14.644
2020	1,405	19.67
2021	0	0
2022	1,599	22.386
2023	1,491	20.874
Total 2019 - 2023	**7,489**	**104,846**

*conservatively estimated average neutralization equivalent of 12.5 $mol_{Alk}/kg_{limestone}$

evaluating data of the hydrological mining monitoring system. Alkalinity demand is given in t as well as M mol, based on an average efficient neutralization equivalent of 14 $mol_{Alk}/kg_{limestone}$. This number was confirmed for both lakes by balancing calculations of executed liming campaigns.

A notable variation of actual annual alkalinity demand between each year as well as differences of demand compared to estimates can be seen. Most remarkable is 2019, in which at both lakes estimated annual demand was surpassed. In 2019, altogether an amount of 3,000 t of lime was added to Lake Störmthal and 1,000 t to Lake Hain.

At Lake Störmthal a second campaign was necessary in 2019 to prevent pH-value dropping to possibly catastrophic levels for existing fish fauna (Fig. 3). Even after input of almost 2,000 t of limestone in spring 2019, acidification made necessary another campaign at the end of 2019. A certain lag of actual neutralization can be seen in 2019 after both campaigns. pH-value tends to react and rise rather quickly, however buffer capacity ($KS_{4.3}$) keeps rising for several months after limestone application before starting to fall due to ongoing acidification. Higher than expected alkalinity demand in 2019 is assumed to be caused by the hydrological dry period from 2018 to 2020, resulting in stronger than average inflow of acidic groundwater.

A first evaluation of the above-mentioned aftercare strategies of the three post-mining lakes was given in Janisch et al. (2022), assessing mainly the year of 2019. Having a time period of 5 years allows for a more detailed evaluation. The year of 2019 can be confirmed as exceptional in respect to alkalinity demand. At Lake Hain for the first and only time thus far actual alkalinity demand reached and even surpassed estimated levels with 12 Mmol/a (Table 1). The years subsequent to 2019 did not reach expected levels of acidification and consequently alkalinity demand. In 2022 no treatment was necessary at all. A strong fluctuation of alkalinity demand at lower than expected levels can be observed.

A comparable, yet somewhat different development can be observed at Lake Störmthal. Alkalinity demand strongly surpassed estimations in 2019 with ≈ 42 Mmol, making a second liming campaign necessary within the same year (Table 2). Fluctuation of alkalinity demand in consecutive years appears to be not as strong as at Lake Hain. In 2021 no treatment was necessary at all. However, those outstanding years of low acidification differing between both lakes (2021 vs. 2022) makes interpretation of its underlying cause difficult.

Conclusions and outlook

Since 2019, alkalinity demand of Lake Hain and Lake Störmthal is met by ship-based liming. This aftercare strategy allows flexible treatment of water bodies that are subject to ongoing acidification, featuring no noteworthy inlets of alkaline river water. Based on the implemented hydrological

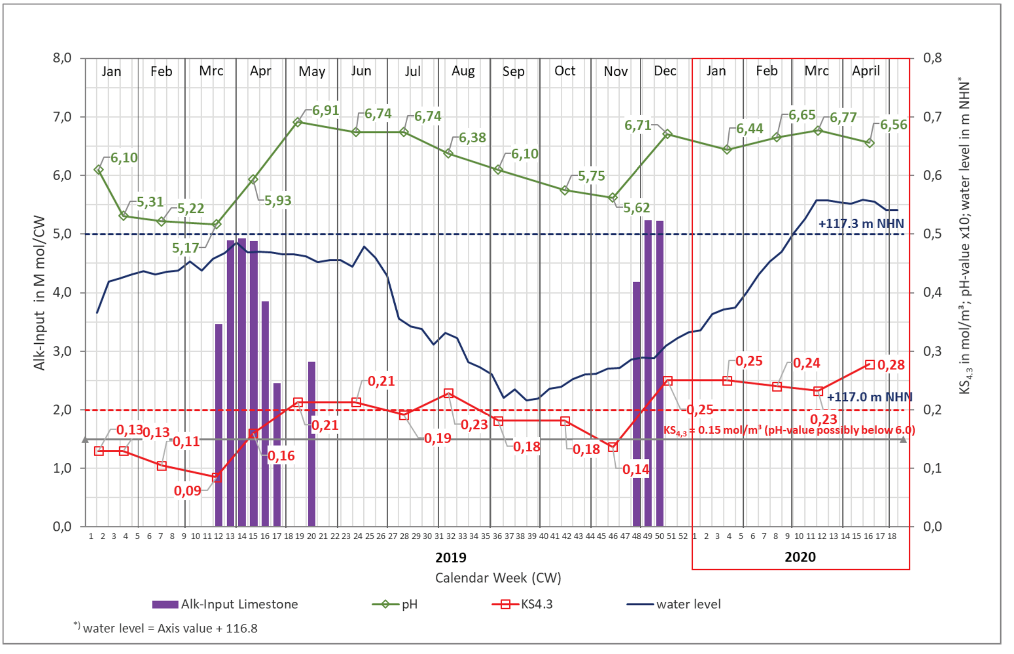

Figure 3 *Overview of monitoring data (pH, $KS_{4.3}$, water level) and alkalinity input at Lake Störmthal throughout 2019 and part of 2020*

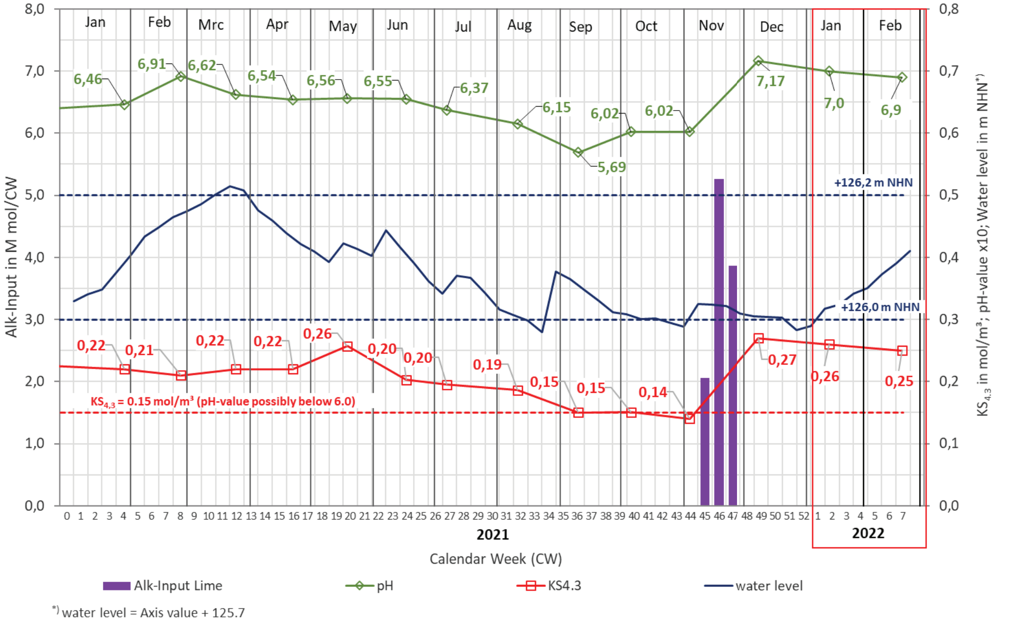

Figure 4 *Overview of monitoring data (pH, $KS_{4.3}$, water level) and alkalinity input at Lake Hain throughout 2021 and part of 2022*

mining monitoring system, water treatment campaigns are operated to guarantee the water bodies' pH-value at ecologically compatible levels between 6 and 8 (Fig. 4). This way it is possible to react to strongly fluctuating demand, covering the full scope of different demand, ranging from years such as 2019 when alkalinity demand strongly surpassed estimations to years with no requirement for a water treatment campaign at all. The cause of observed high interannual variations of alkalinity demand cannot be fully explained, showing the demand for further hydrological and limnological research. This way, a reliable estimate of the long-term acidification and resulting alkalinity demand could be achieved as well.

After assessing 5 consecutive years of aftercare of the three lakes, the conclusions of Janisch et al. (2022) can be confirmed. Where available, alkaline external surface water (1) can be used to meet alkalinity demand and counter ongoing acidification (Lake Zwenkau). In absence of any noteworthy receiving waters (Lake Störmthal & Lake Hain) or in case of insufficient availability of external surface water, ship-based liming (2) can be applied for the same results. This way, the LMBV has permanent and reliable means to ensure the water quality requirements of the three largest post-mining lakes in the south of Leipzig.

All three post-mining lakes are subject to ongoing acidification. According to latest limnological predictions, inflow of acidic groundwaters into the lakes´ water bodies will continue beyond 2050, necessitating appropriate aftercare to guarantee water quality.

Acknowledgements

Mine reclamation is always the work of many people and decades. Therefore, many colleagues from LMBV, partners from research and consulting institutions and authorities contributed to what is presented here.

References

Totsche O, Lucke B, Benthaus FC, (2018) In-lake neutralization of mine lakes – 15 years of continuous development. Mine Water – Risk to Opportunity (Vol I), p. 199 – 204; Pretoria, South Africa (Tshwane University of Technology, ISBN 978-0-620-80650-3

Janisch B, Rumpel M (2022) Aftercare Strategies to Ensure the Water Quality of Post-Mining Lakes in the South of Leipzig. Wasserwirtschaft S1 / 2022, p 100 - 101, ISSN 0043 0978

Schlenstedt J (2020) Preparing the Ground for the Future, https://www.lmbv.de/wp-content/uploads/2021/10/LMBV-Broschuere-Rekultivierung-englisch-WEB-1.pdf. Accessed 21 Feb 2024