Potash Dump Leachates – Challenges from Environmental Regulatory Requirements and Climate Change

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Abstract

In a German former potash mining district, highly saline leachates (120 g/L chloride) from three potash dumps are collected in a basin and discharged into the receiving river in a controlled manner. This work illustrates the increasing constraints but also obstacles towards management of saline dump leachate that does not rely on dilution. Besides dump covering, evaporation of leachate is considered the most promising approach to reduce salt load into surface water in the long term and is currently put forward. Here, linking energy and material fluxes on a local basis is pivotal during development of a feasible process.

Keywords: European Water Framework Directive, Germany, Circular Economy, Active Treatment, Evaporation

Introduction

Rich potash salt deposits in the German Southern Harz region have been mined since the 1890s. This contributed to the former German Democratic Republic (GDR) being the third largest potash producer in the world in the 1980s. Mining largely ceased in the wake of German reunification in 1990. Until now, however, deposits at six large potash mining dumps with a total volume of 177 million m^3 are affecting the environment in the Southern Harz region. Their highly saline leachates are characterized by chloride concentrations around 120 g/L and TDS 200 g/L. Since 1992 leachate collected from three of the dumps – Bischofferode, Sollstedt and, if not used for underground backfill, Bleicherode – and local industrial processing wastewater is directed into a basin in Wipperdorf. From there it is discharged into the receiving Wipper River in a controlled manner. In this way about 250.000 m^3 leachate, corresponding to about 30 kt chloride, is annually discharged to the Wipper River without treatment.

Since 1994 state funds have been used to rehabilitate the mining legacies of the former GDR, where Lausitz and Central-German Mining Administration Company (LMBV) is responsible for the potash sites nowadays. According to the European Water Framework Directive (WFD, European Commission 2000) the status of surface and groundwater bodies in the member states must achieve a good chemical and ecological status latest by 2027. The surface water body "Lower Wipper (2)", which belongs to the study area around the Wipperdorf basin, however, is heavily modified with bad ecological potential and a not good chemical status (TMUEN 2016). Main reasons for this are its obstructed water course and the burden from agriculture and potash mining.

Basing on WFD's and further regulations' improvement requirement on the one hand and changing hydrometeorological boundary conditions on the other, the current leachate load control system is increasingly no longer able to comply with regulatory limits. This

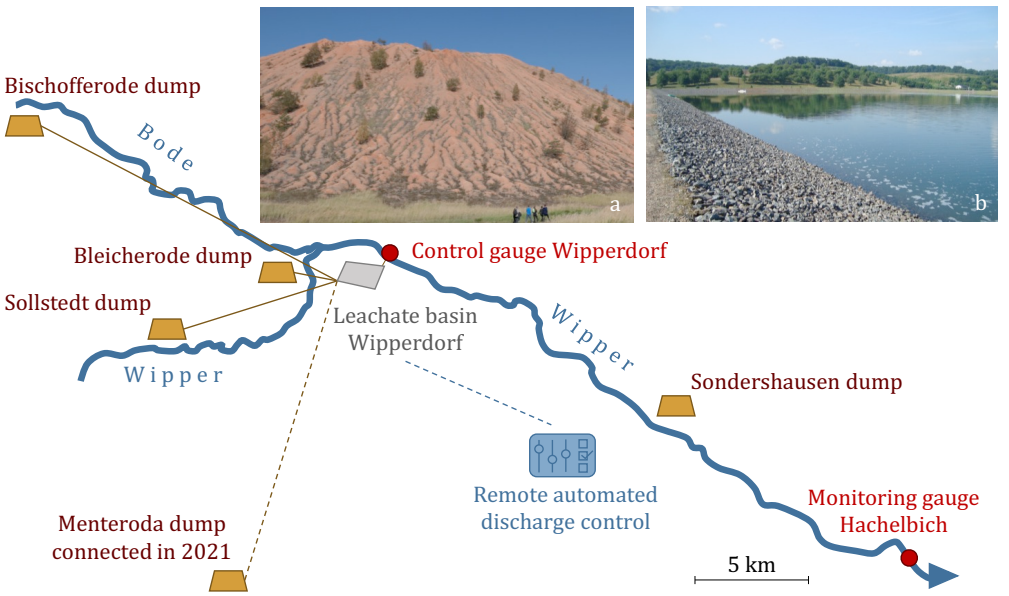

Figure 1 Location of potash dumps, Wipperdorf leachate basin and relevant gauges within the leachate load control system at the Wipper River. a: Bischofferode potash dump, b: Wipperdorf leachate basin.

paper presents the current approach to achieve a load reduction in the Wipper River to address this. In addition, practical experiences from the cooperation with the responsible authorities as well as the causes that led to the implementation of this approach (only) now are shown.

Current state of regulations and measures

In the study area (Fig. 1), environmental pollution from potash mining is reflected in high salt concentrations in groundwater and streams, which is monitored by its key parameter chloride concentration. Right before the point of discharge from the Wipperdorf basin, concentrations around 0.6 g/L Cl are common at mean flow conditions of the Wipper River. About 1 g/L Cl at dry conditions represent the geogenic and mining influenced background concentration that is prevalent in the inflowing groundwater. Directly downstream the potash dumps up to several tens of grams per liter chloride are measured in groundwater monitoring wells. In light of already long-lasting and large-scale salt pollution in the Lower Wipper surface water body it is not seen possible to achieve the chloride concentration limit of 200 mg/L defined in the WFD for a good chemical status by 2027.

Since 2008 a modified official order from the Thuringian State Mining Authority prescribes the conditions for discharge of leachate from the Wipperdorf basin into the Wipper River. Chloride concentration limits for the 27 km downstream gauge Hachelbich set therein take into account the results of comprehensive studies on the possible reduction of the salt load into the river. An annual mean limit value of 1.5 g/L was defined. In addition, a 90th percentile of the 2-hour composite samples of 1.6 g/L was set to reduce concentration fluctuations which would represent an added burden for flora and fauna.

To comply with these limits, the following measures are being implemented which reduce both controllable (discharge from the basin, capture of dump leachate) and uncontrolled (uncaptured dump leachate, geogenic background) chloride loads:

- continued covering of potash dumps,
- safeguarding measures to collect dump surface runoff during heavy precipitation events,

- rehabilitation of Wipperdorf basin, buffer basins, and existing leachate pipelines,
- revision and reconstruction of the existing discharge control system towards an automated discharge control comprising a monitoring system, a database, and a control software.

In addition, representatives of involved authorities, the remediation agency LMBV, and external experts meet twice a year to inform each other and to discuss current issues as well as further measures for the improvement of water quality.

Reasoning and obstacles towards proactive water pollution control

With the above-mentioned measures, the limit values at the Hachelbich gauge have generally been well complied with in recent years. However, with the following, partly new, boundary conditions it has become clear that these measures will not suffice in the future:

- Firstly, relying mainly on dilution to meet regulatory limits is not in agreement with WDF's intention. Consequently current regulations for the site also demand that the salt load to water bodies in the Southern Harz potash district be further reduced.
- As it depends on the water flow in the Wipper River, the current controlled leachate discharge into the Wipper River is limited by hydrometeorological conditions. The last three consecutive dry years 2018 – 2020 have vividly demonstrated the climate prognosis for the region, according to which decreasing precipitation is to be expected throughout the year, especially – as here – in the lee area of mountain ranges. Increase in temperature enhances evaporation towards an even more negative regional water balance.
- Above this, leachate from a further potash dump Menteroda will be directed to the Wipperdorf basin latest in 2022. Subsurface backfill of leachate at this site is to be discontinued with the mining cavities being filled.
- Covering the dumps can effectively slow down the salt load into ground and surface water in the long term. Progress in covering the dumps, however, is limited by the availability of covering material. For the largest dump Bischofferode (53 Mm^3), which is not sealed against the subsoil and the only one not yet being covered, the framework operating plan for covering is currently being drawn up. Though, it will take years until full coverage and a following substantial reduction of salt leaching.
- Every 10 minutes the automated salt load control system calculates the possible discharge from the Wipperdorf basin based on current measurement data. This system is designed to prevent the concentration limit from being *exceeded*. Due to the system-immanent duration of transmission cycles and partly high-frequency flow fluctuations in the Wipper River, there is only minor potential to further optimize the control system towards an increased *utilization* of the approved concentration limit.

Urgency to implement further measures is shown by the fact that hazard prevention measures had to be carried out in the past two winters to prevent the Wipperdorf basin from overflowing. The Thuringian State Office for the Environment, Mining and Nature Conservation (TLUBN) tolerated elevated chloride concentrations of 1.8 g/L at the Hachelbich gauge as long as the water temperature was below 10 °C. As a result, the leachate level in the basin could be substantially reduced and overflow during the dry summer months has been prevented so far.

Various measures are currently being examined that could contribute to an improvement in the ecological state of the surface water body *and* to the safe operation of the Wipperdorf basin. Among them a feasibility study is in progress which evaluates construction and operation of a pipeline from the Wipperdorf basin to a farther downstream river. Considerably higher flow there would allow to discharge captured dump leachate with less effect on salt concentrations. Apart from a not yet clarified feasibility this approach again relies on dilution. Furthermore the project would have high cost expenditures and would have to meet strict formal requirements. Consequently, the most promising approach to

reduce salt load into surface water in the long term is considered evaporation of leachate which is currently put forward and described below. Reasons why this approach is only now being seriously pursued are manifold:

- Even if evaporation seems to be the silver bullet to reduce salt load in the river section of the surface water body Lower Wipper, it is only one of many measures that have been and are being investigated since about 15 years. Other, less costly measures were considered sufficient until the onset of the above mentioned change in boundary conditions.
- Planning and eventual implementation of these initially prioritized measures was very laborious. In conjunction with their regular duration and the iterative procedure a lot of time passed. Furthermore, high formal requirements are connected with the announcement, documentation, and subsequent evaluation of security measures by the responsible authorities. Experience from everyday work shows that compliance with bureaucratic regulations requires a great deal of additional effort, which sometimes stands in the way of efficient implementation of more courageous measures.
- There is no standard technology or process which can guarantee the production of a usable salt from the leachate. Therefore, adaption and optimization to site conditions of this laborious and energy-intensive process requires prior research which further increases the time horizon to implementation as well as the financial expenditures. Especially high operating costs force towards an energy-efficient approach with the target to obtain a marketable product (circular economy).
- Still, the question of proportionality is not raised for the planned evaporation plant. As long as – in this case – the public sector pays for the remediation this seems not to be an argument for water authorities which focus mainly on water quality but less on the total environmental footprint of extensive remediation measures.

Way forward

Alternative strategies for leachate management had to be found in order to prevent overflow of the Wipperdorf basin in the long term and to better comply with the central idea of the WFD. Leachate evaporation with recovery of a usable street salt product is hereby considered as an approach to reduce the total leachate load to the environment. Consideration is also being given to using the leachate as a de-icing agent.

With regard to the processing of leachate into a road salt or a brine as de-icing agent the major challenge is to achieve an appropriate purity and NaCl content of the product. In Germany, requirements regarding the quality of a salt or brine that can be used in winter maintenance are specified in the standards of DIN EN 16811-1. In this context, German standards for the chemical composition of road salts pose a special challenge as they are much stricter than in other European countries. The minimum sodium chloride content of the road salt is 97 wt% in Germany and 90 wt% only in other EU countries. Brine that can be used for winter service must have a sodium chloride content between 18 wt% and 26 wt% in Germany and other European countries.

Figure 2 provides an overview of the possibilities and requirements mentioned related to typical chemical composition for the current leachate and the necessary treatment steps derived from this. In addition, the objectives of past, current and possible future projects are presented.

Currently a pilot plant is in operation where leachate from the Bischofferode potash dump is concentrated to varying degrees by a vacuum evaporator. In further processing steps, the product salt is washed and centrifuged to increase purity and to dry the salt. Because evaporation is very energy consuming, different scenarios for utilizable energy sources have to be assessed (e.g. renewable energy sources, heat extraction of a nearby biomass power plant, use of fossil fuels).

Figure 3 shows the chamber of the vacuum evaporator and a vessel of the produced salt along with the NaCl content achieved in pilot

Leachate (Bischofferode potash dump)

NaCl content of leachate (2012 – 2020): 9 wt% – 24 wt% (mean: 15 wt%)
NaCl content of leachate TDS (2012 – 2020): 81 wt% – 97 wt% (mean: 94 wt%)

	Brine as de-icing agent	**Road salt**
Required NaCl content (DIN EN 16811-1)	18 wt% to 26 wt% NaCl	≥ 97 wt% NaCl
Necessary treatment	Concentration-dependent: thickening of the leachate, filtration to reduce filterable substances	Suitable process for salt separation and achieving the necessary quality
Previous studies and considerations	Analysis of existing data and determination of further relevant data regarding the requirements for winter maintenance products; contacting winter services	Carrying out hydrochemical modelling and laboratory tests (partial evaporation and washing of the salt) to increase the purity of the product salt; tests with the leachate of Wipperdorf basin, which has a lower NaCl content of TDS
Current project		Pilot testing at the Bischofferode dump site: partial evaporation with a vacuum evaporator and washing of the salt
Further project ideas	Cooperation with winter services and first pilot tests	Large-scale plant: depending on the success of the pilot project and the objective
Advantages and disadvantages/ obstacles	+ low treatment effort and energy demand - only useful in winter - cost-neutral/profitable only in the close vicinity → limited utilisable quantity	+ salt production can be carried out all over the year → permanent reduction of the salt discharge - high energy demand, cost-intensive - recovery/disposal of residual/waste products must be clarified

Figure 2 *Requirements and site specific prospects for the utilization of leachate in winter service.*

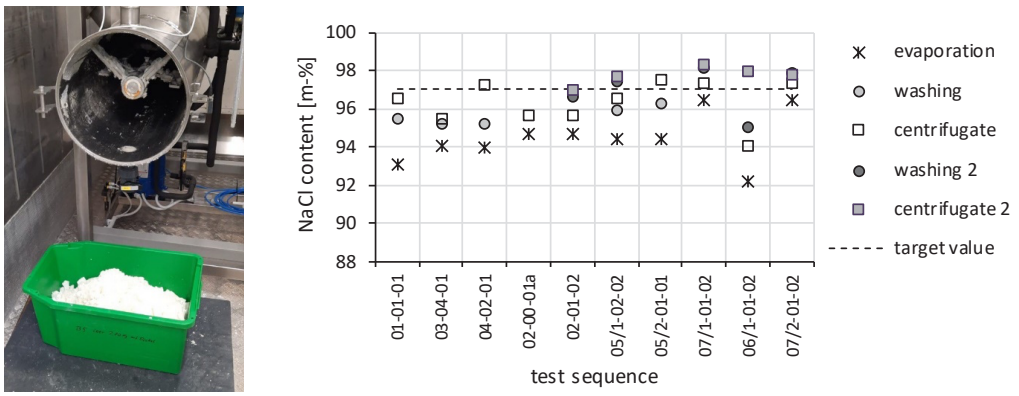

Figure 3 *Chamber of vacuum evaporator and produced salt (left); results of pilot tests: measured NaCl content after each treatment step (right).*

tests. According to this, the required purity of the salt of 97 wt% NaCl can be achieved, when the leachate is only partially evaporated (from the fifth test on). Future tests will show which degree of evaporation and which washing ratio are favorable with regard to achieving the necessary quality and the largest possible product quantity. In future tests, the process will be evaluated with regard to compliance with other quality criteria placed on road salt.

Conclusions

Through LMBV billions of Euros were already spent for rehabilitation of mining legacies on the territory of the former GDR. It can be seen as a lucky circumstance that public funds are provided to this extent. Though, because the use of public funds is strictly regulated, a disadvantage that emerges in the daily remediation business can be seen in a bureaucracy that sometimes hinders swift implementation of measures.

Due to the high costs for treatment of leachates and for other measures to improve water ecology, the responsible mining authority and upper water authority are in a great tension between necessity and appropriateness. Therefore, the **proportionality** of measures must be discussed again and again between all partners involved in the remediation process. Further, the questions "How much remediation can we afford?" or "How much remediation do we want to afford?" will not be answered until ecosystem services of remediated streams can be determined in more detail. Discussion on this issue is just beginning (e.g. Stowasser *et al.* 2021). With the Fauna-Flora-Habitat region "Inland Salt Station at the Ronnenberg Potash Plant", established in 2007, there is a German example of an anthropogenic inland salt site, recently placed under natural protection as valuable habitat (Brock *et al.* 2007). Because this approach may conflict with remediation goals, it remains questionable whether it could be a feasible long-term option for selected locations at the current site.

Above described experiences during implementation of regulatory requirements demonstrate that individual water protection measures must be designed and considered more strongly with respect to economic efficiency and proportionality. Further, site specific linking of energy and material fluxes is pivotal during development of a feasible water treatment process. Thus, the target in the current case should be to gain a marketable product from saline leachate evaporation.

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