Sustainable salt management in mine affected surface waters

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Abstract

Water treatment is for a key process during and after the remediation of the tailings ponds at the former uranium processing site Seelingstädt and the flooding of the former uranium mine Ronneburg. For that reason Wismut GmbH operates water treatment plants at each site in the eastern part of Thuringia.

The plants were designed for the removal of uranium, manganese, arsenic and metals from the mine water by using lime precipitation. Beside these contaminants, the mine water contains high concentrations of sulphate, chloride, calcium and magnesium. These compounds cannot be separated by the established technology.

Treatment plant flow rates need to be managed according to the respective flow situations in the receiving creeks and the river Weiße Elster influencing the flooding level in the Ronneburg mine and the hydrological situation at Seelingstädter TMF site. Especially in dry season, the local water management is a very challenging task.

The availability of water is a limiting factor and does not allow lower salt concentrations especially in the Culmitzsch creek. Other alternative technologies are currently under investigation in various lab and pilot scale experiments aiming for a technical solution fulfilling the main criteria for long-term suitability. At the moment, membrane techniques seem to be favourable. But there are still a number of open questions concerning the implementation of this technology at the site. The problem of handling residues is not resolve at the moment. So it is still necessary to proceed with R&D activities.

Keywords: salt management, water treatment, sulphate, chloride, hardness

Introduction

Water collection and treatment are key processes during and after the remediation of the tailings ponds at the former uranium processing site Seelingstädt and the flooding of the former uranium mine Ronneburg. For that reason, Wismut GmbH operates water treatment plants (WTP) at both sites.

The WTPs were designed to remove uranium, manganese, arsenic and metals from the mine water by lime precipitation. In the Seelingstädt WTP, lime precipitation is used in combination with a stripping pre-treatment step to remove carbon dioxide. Beside these constituents, the mine waters contain high concentrations of sulphate, chloride, calcium and magnesium. These compounds cannot be separated by the applied technology. In case of chloride, even a concentration increase occurs due to the stripping technology.

The recipients of the outflow from the treatment plants are small creeks. At all sites, the water quantity and quality in the creeks is dominated by the output of the respective treatment plant. Both receiving creeks are tributaries of the river Weiße Elster. Treatment plant flow rates need to be managed according to the respective flow conditions in the receiving creeks and the river Weiße Elster. The resulting management of water discharge influences the flooding level in the Ronneburg mine, which is managed by mine water discharge into a drainage system and mine water release from an artesian well. At the Seelingstädt site, limitations of the water discharge may lead to a delay of the TMF remediation. The geotechnical stabilisation of the tailings ponds depends on tailings consolidation by continuous release of highly mineralised pore waters. Especially in dry season, the local water management is a very

Table 1 comparison of the concentrations (discharge WTP) to the limited values in the creeks

Site	parameter	average (max. Conc.)	limit	ratio average (max) conc/limit
Seelingstädt (Culmitzsch creek)	Cl in g/L	1.2 (1.7)	0.9	1.4 (1.9)
	SO_4 in g/L	6.3(10.0)	5.0	1.3 (2.0)
	Hardness in °dH	245 (398)	180	1.4 (2.2)
Ronneburg (Wipse creek)	Cl in g/L	0.01 (0.18)	0.5	0.1 (0.4)
	SO_4 in g/L	2.3 (3.1)	3.0	0.8 (1.0)
	Hardness in °dH	143 (193)	230	0.6 (0.8)

challenging task due to the limited dilution in the surface water.

The salt management system operates in two simultaneous steps (first step – creek management; second step – Weiße Elster management).

Salt management in the receiving creeks Culmitzsch and Wipse

There are no regulatory limits for sulphate, chloride and hardness emissions from the treatment plants themselves. But there are limits for the surface water quality several hundred meters downstream of the discharge points. A comparison of the average concentrations in the discharged waters with the limits to be met in the creeks is given in table 1.

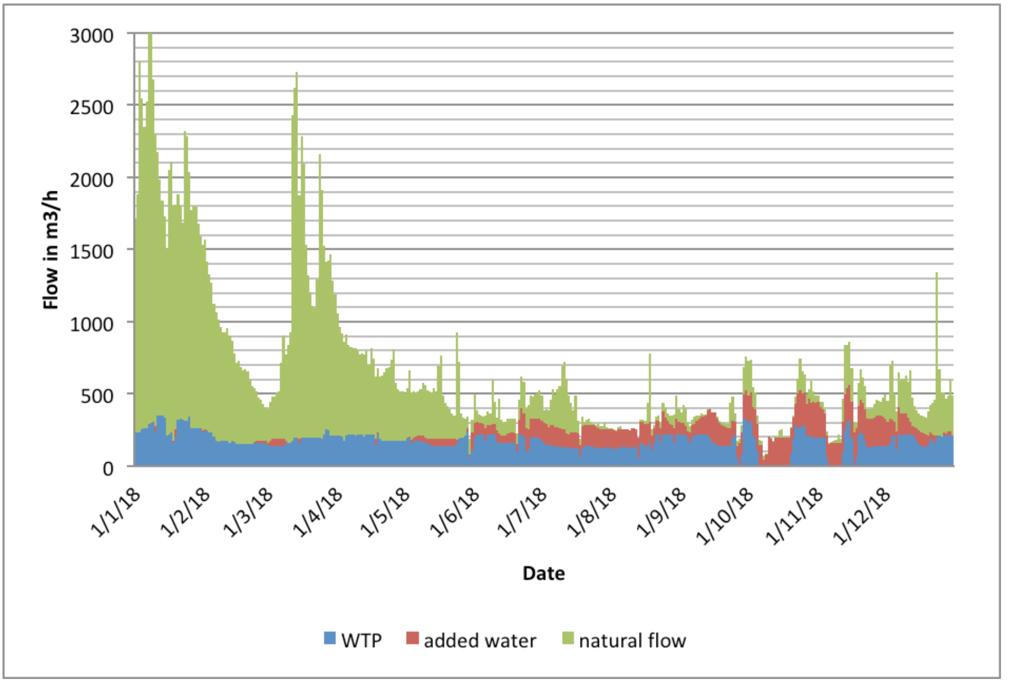
Due to the limited natural discharge in the receiving creeks the effect of the dilution in the creeks themselves is limited. Therefore, water is pumped via a 20 km pipeline from the River Weiße Elster to be discharges into the creeks allowing to actively manage the salt concentrations (. At maximum, 250 m^3/h of river water can be added into each creek.

Water samples are taken at different points (inflow and discharge of the WTP, Culmitzsch or Wipse creek, the river Weiße Elster) once or twice per day. These data are used together with other input data (the upstream flow situation in the receiving creeks and the river Weiße Elster as well as the discharge of the WTPs) to calculate the maximum throughput of each WTP. With the help of a software the influence of the output of the WTPs as well as variations of the upstream concentrations on the water quality downstream of the discharge points can be assessed. On the basis of these calculations, the necessary quantity of river water from the Weiße Elster to be released into the respective creek is permanently adapted. The results of this stepwise adaption are shown in figure 1. The diagram shows two different situations. The first half of 2018 is considered a typical meteorological situation. An addition of river water from the Weiße Elster was only necessary occasionally. In the second half of the year, Thuringia was afflicted by a prolonged drought. Without addition of the riverwater, discharge from water treatment would not have been possible at Seelingstädt site.

At the Seelingstädt site contaminated water can be stored for 10 days. A stop of water treatment for more than 10 days would lead to a stop of other remediation activities because working areas would be flooded. In times with a low natural flow, the maximum water treatment capacity is reduced from 330 m^3/h to 200 m^3/h. This is due to the limited availability of river water (max. 250 m^3/h) and the high salt concentrations in the released waters from the WTP.

At the Ronneburg mine site a permanent discharge of contaminated mine water occurs into a drainage system in the Gessental valley. Therefore, a permanent treatment is necessary. A stop of water treatment for longer than a week is difficult to handle. The focus for the salt management is sulphate at this site.

General data characterising the amendment of the natural discharge in the receiving creek compared to the quantity of mine waters treated are given in table 2 for the year 2018. They show how essential the adding of river-water is for the operation of the two treatment plants. Only with this



***Scheme 1** Mixture of the water flow in the creek Culmitzsch in 2018*

***Table 2** Data of the current salt management*

Site	treatment	WE-Water	Costs
Seelingstädt	1.51 Mio m^3	0.75 Mio m^3	0.35 Mio €
Ronneburg	1.90 Mio m^3	0.46 Mio m^3	0.25 Mio €
sum	3.41 Mio m^3	1.21 Mio m^3	0.6 Mio €

measure the prescribed limits in the receiving creeks are to be met. Cost driving factor is the power supply for the pumping of the water, maintenance of the supply pipeline, sampling and analytics.

Management of compliance with limits in the Weiße-Elster

The receiving creeks Culmitzsch and Wipse are tributaries of the river Weiße Elster. In addition to the limits in the two creeks, there are prescribed limits for chloride, sulphate and hardness in the Weiße Elster, too. The limits of hardness vary depending on the flow conditions and water temperature.

Especially during dry season the natural flow in the river Weiße Elster can be critical in respect to the water discharge from the remediation sites. To prevent an interruption of water treatment and as consequence of the remediation works Wismut contracted the management of the storage reservoir Pöhl situated upstream of the remediation sites in the catchment area of the Weiße Elster river. This storage reservoir has multiple functions. It is used for flood prevention, recreation as well as regulation of minimum discharges downstream. These management objectives partly contradict especially during the dry season. The total storage volume of the reservoir is about 62 Mio m^3, with about 32 Mio m^3 available for the low flow management. Based on the Wismut contract the operator has to stabilize the flow in the river Weiße Elster upstream of the water discharges and thereby to ensure a minimum discharge in the river of 3.5 m^3/s at the gauging station Greiz. Nevertheless, it is the task of Wismut to harmonize the output of the WTPs Seelingstädt and Ronneburg taking

Table 2 Comparison of different technologies

technology	Useful for				Max. achievable separation in %			
	Mg	Ca	Cl	SO_4	Mg	Ca	Cl	SO_4
Feed of WE-Water (current technology)	x	x	x	x	-	-	-	-
Evaporation	x	x	x	x	99	99	99	99
Ionenexchange [Ruhland]	x	x	x	x	70 -90	70 -90	70 -90	70 -90
Reverse osmosis [GEOS]	x	x	x	x	99	99	99	99
nanofiltration	x	x	-	x	99	99	35	70 - 99
membranelektrolyse [Friedrich]	x	x	x	x	25	97	93	90
Bipolar elektrodialysis	x	x	x	x	8	6	25	16
Bariumchlorid [GEOS]	-	-	x	-	-	-	-	99
Precipitation of ettringit [GEOS}	x	x	-	x	99	99	-	99

into account the discharge condition in the river and the water inflow at the remediation sites. The level of 3.5 m^3/s does not allow a simultaneous output at the maximum treatment capacity at both WTPs. In addition to the management of the discharge from the Pöhl reservoir the much smaller Weida reservoir allows an additional amendment of surface water to the river Weiße Elster as another temporary measure but with just limited effect.

Basis for the discharge management are a daily sampling in the river Weiße Elster, observing the present water flow, evaluating the accruing mine water quantities and qualities taking into account the past and present weather conditions as well as the progress of the remediation works. Based on this analysis priorities are set which have implications on the remediation works. Based on these priorities the discharges are adapted where the site with higher priority is allowed a higher discharge, while at the other site the treatment capacity is reduced. Another important boundary condition for the discharge management is the lag time for the water flow between the discharge points as well as the gauging station and the monitoring point where the limits have to be met. This lag time is pretty similar for both flow between 7 and8 hours. That means that the whole system shows sluggish reactions, which is a challenge for discharge management.

A crucial factor for the discharge management is the availability of stored water in the storage reservoir Pöhl over the whole year. In 2018 the lower limit of the storage water level was reached for the first time. The discharge of water had to be remarkably reduced from 3.5 m^3/s to 2.3 m^3/s. As a consequence the discharge from the sites had to be more stringently managed using all available storage volumes at the sites.

Further Development

Despite the presently implemented management of salt concentrations in the receiving creeks and the river Weiße Elster additional R&D activities are conducted to further reduce the discharge of salt from the remediation sites as it is required also by the permitting authorities. According to a permitting with a stepwise reduction of limit values the limit for sulphate in the Wipse creek will be as low as 800 mg/L by 2020. The current technical system is limited by the capacity of pipelines and pumping stations which are necessary for transportation of river water to be added into the receiving creeks.

Therefore, technology development for salt removal from mine and seepage waters is underway. Different treatment technologies (nanofiltration, reverse osmosis, addition of Barium chloride, evaporation) are assessed. Economic constraints are important for the comparison of the current solution discharge management with the implementation of the new technologies.

In our understanding in terms of water treatment a sustainable solution includes the following 5 criteria:

1. Predominant use of renewable natural resources
2. restricted carbon dioxid footprint
3. Aiming to get marketable products instead of a considerable amount of residues to be disposed of
4. No need for long term supervision, self containing systems
5. Negligible effect on ecosystems and future generations

None of the salt management technologies performs well in terms of the 5 criteria defined. The current technology benefits from the existence of a water resource upstream, the storage reservoirs. It is clear that construction of additional water storage capacity would cause more than a negligible effect on nature.

Different studies showed that it is very difficult to produce marketable products from the residual brines at acceptable conditions due to the nature of the treated waters originating from former uranium mining and processing sites. The last step is mostly a precipitation of salts (for example gypsum). One critical point is that a nearly uranium (and decay products) free solution is needed to avoid enrichment of uranium, radium and other radioactive isotopes in such a product. This is still an unsolved problem. In a pilot plant we want to investigate this point in more detail. The test will start in summer of this year. The currently used lime precipitation technology allows to reduce the uranium concentrations reliably to about 0.1 mg/L and less depending on the site conditions. If it is not possible to produce marketable products, a dumping of treatment residues is necessary. The deposit of wastes may lead to higher expenses for long term supervision and deposits have to be insoluble to avoid later mobilisation. This is especially in case of salts difficult to achieve and contradicts the 4th criterion for sustainable technologies.

Conclusions

Water treatment is a key process during and after the remediation of the tailings ponds at the former uranium processing site Seelingstädt and for the flooding of the former uranium mine Ronneburg. The current system of salt management ensures a stable water treatment at both sites, since it allows WTP's discharge into receiving creeks in compliance with salt regulation limits. The use of river water to dilute salt concentrations and the use of upstream water storage reservoirs to allow a sufficient flow are considered sustainable solutions. At the moment, this technology is state of the art, allows a stable process of water treatment and thereby, remediation of the former uranium mining and milling sites. Nevertheless, even with all regulatory limits are met, it constitutes a remarkable effect on surface water quality. The availability of water is a limiting factor and does not allow lower salt concentrations especially in the Culmitzsch creek. Other alternative technologies are currently under investigation in various lab and pilot scale experiments aiming for a technical solution fulfilling the main criteria for long-term suitability. At the moment, membrane techniques seem to be favourable. But there are still a number of open questions concerning the implementation of this technology at the site. The problem of handling residues is not resolve at the moment. So it is still necessary to proceed with R&D activities.

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