Water management at the former uranium production tailings pond Helmsdorf

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Abstract

Remediation of the tailings pond Helmsdorf, the second largest tailings management facility (TMF) from former East German uranium production, is a major project of Wismut GmbH. The remediation strategy consists in dry stabilization, soil covering and dams reshaping for long-term stability. It allows free discharge of surface water and seepage water collection for treatment. Water management has played a key role for the progress of remediation right from the beginning.

In 1995 a newly-built water treatment plant (WTP) started running to clean up the pond and seepage water prior to its discharge (main contaminants: As, U, Ra-226). During operation of the WTP, the technology has been modified several times for different reasons: changes in water quality and pollutant speciation, economic reasons, adaption to changes in water catchment. All of these modifications and measures for maintenance had to be managed while water treatment was running continuously.

To prepare for a future long-term water treatment focusing on seepage cleanup only, several treatment technologies were examined. The site specific performance of the most favourable technology – ion exchange in combination with adsorption – was tested in a pilot plant. In addition, hydrological estimations were made to evaluate the amount of contaminated seepage water after final coverage. On this basis, a new WTP is currently planned. Water treatment will be performed by that new WTP from 2020 onwards.

Keywords: TMF, uranium, arsenic, radium, water treatment, operational technology modifications

Introduction

Remediation of the tailings pond Helmsdorf, the second largest tailings management facility (TMF) from former East German uranium production, is a major project of Wismut GmbH.

The Helmsdorf tailings management facility was established by the damming of two valley locations. It was operated from 1958 to the shutdown of ore processing in 1989. Some data on the starting conditions of remediation are given in table 1.

The remediation strategy is:
Removal of pond water, followed by interim covering, dewatering, contouring and final covering of the tailings; vegetating for erosion protection and afforestation of covered tailings areas.

Water management has played a key role for the progress of remediation right from the beginning.

Its task was to create the conditions for further cover of tailings and avoid the outflow of seepage water from the dams into natural water bodies. In our understanding, water management consists of

- catchment of contaminated water,
- water treatment and
- discharge of uncontaminated water to receiving waters.

The three key aspects of water management are interconnected and influenced by the remediation process. The focus of this paper is on water treatment and its operational modification.

Water drainage and treatment causes about 22% of the overall operational site remediation cost of ~130 million €.

Table 1. *starting conditions for water management and remediation*

Tailings area	ha	200
Water cover	ha	116
Volume supernatant water (pond water)	Mm^3	5
Maximum tailings thickness	m	55
Maximum water depth	m	14
Pond water concentration of U	mg/L	6.5
Pond water concentration of As	mg/L	120
Pond water concentration of Ra-226	mBq/L	800
Pond water concentration of SO4	g/L	6
Pond water concentration CO3/HCO3	g/L	5
Pond water pH		9

Water treatment during remediation

Two different technologies have been used since starting water treatment. From 1995 until 2003, ion exchange in combination with flotation was applied. Since the reconstruction of the WTP in 2003, lime precipitation has been used. (see figure 1). Until now, nearly 26 million m3 of contaminated water were treated (50 % cleaned up by ion exchange/ flotation and 50 % by advanced lime precipitation).

The following aspects required operational modifications in the water treatment process:

- Changes in water quality by natural processes
- Increasing turbidity of the contaminated water
- Changes in water drainage regime
- Cost optimizations
- Progress in site remediation

Changes in water quality

The pond water was characterized by very low nutrient concentrations except for phosphate. Nevertheless, the C:N:P ratios resulted in the occasional growth of algae in the summer periods. The elevated summer concentrations of algae strongly affected ion exchange in the water treatment. It led to coatings on the exchange resin and resin washing had to be performed more frequently. The lime precipitation technology is much more robust in this respect. However, high algae concentrations lead to a rise in chemical oxygen demand (COD), which is a regulatory monitoring value as well. Experiments with special activated carbon and the addition of oxidation agents did not show any effect on COD. In this case, we were successful in reaching an arrangement with our national authorities allowing for higher discharge limits (30 → 80 mg/l).

Algae growth moreover led to the formation of a layer of dead organic material with a thickness of maximum 1 m on the tailings pond surface. Thereby a reduction zone developed in deeper pond zones and arsenate ions were reduced to arsenite ions. The remaining arsenic effluent concentrations after treatment were in accordance with regulatory limits but, nevertheless, led to higher fish toxicity in the receiving waters. Therefore, a simple air oxidation step was added. After 2004, aeration was replaced by pre-oxidation in the stripping columns.

Changes in water drainage regime

The pond water concentrations were reduced stepwise by rainfall dilution whereas the seepage concentrations stayed on a higher level. Since the year 2012, the former pond water was eliminated nearly completely. Only the deepest point of the tailings pond got regularly refilled after heavier rainfalls. To ensure an ongoing remediation in the central (deepest) area of the tailings pond, a separate storage and homogenization pool (SHP) was built (volume 40,000 m^3). By pumping the pond water to the storage pool, the deepest areas of the pond could be kept dry without reaching the capacity limits of the WTP.

The seepage water generally showed a higher concentration than the pond water body or the water in the storage pool. With a decreasing inflow of uncontaminated waters to the pond / pool, the characteristics of surface and seepage waters were converging. Especially in dry periods the concentrations

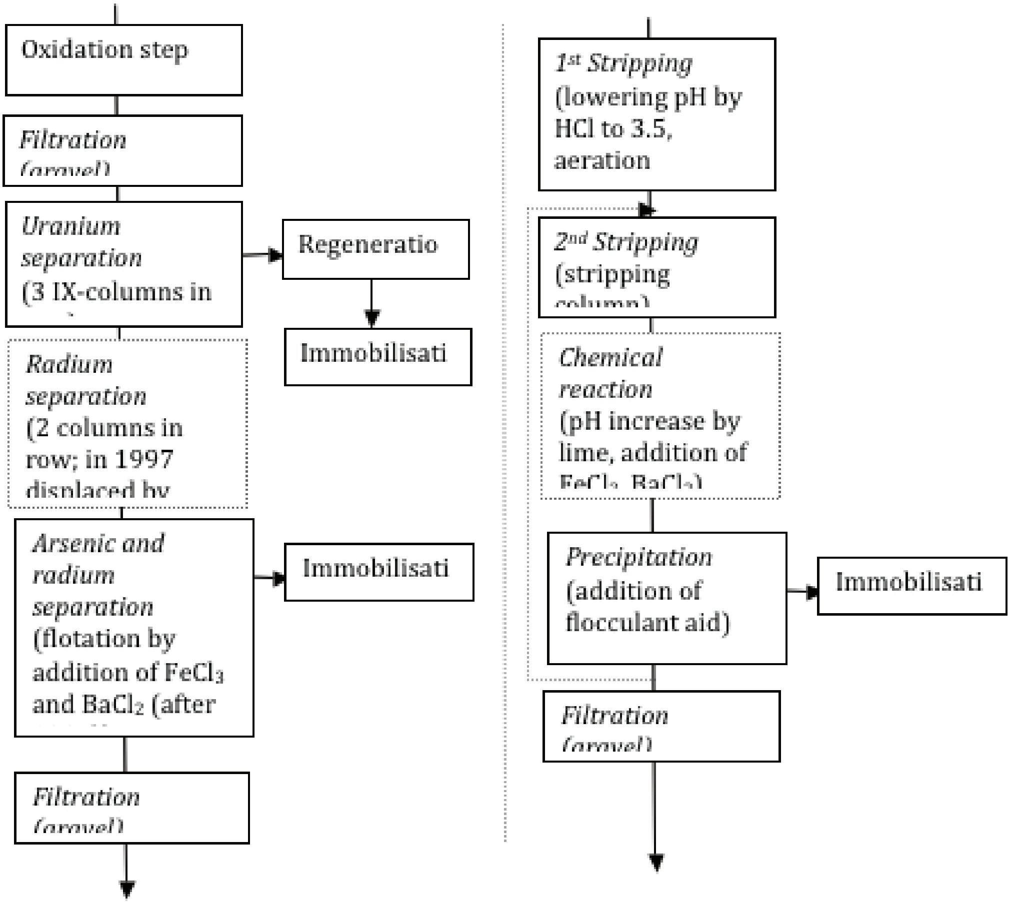

Figure 1 Technological schemes of water treatment at Helmsdorf site (left: 1995 -2003, right: 2003 – now)

in the SHP rose continuously. These elevated pollutant concentrations did not allow to operate the WTP at its maximum capacity. Recirculation of treated water became necessary in order to stabilise the separation of uranium. About 50 % − 60 % of the treated water had to be recirculated. The maximum throughput dropped to 60 m^3/h.

To prevent calcination in parts of the pipeline system, anti-scaling agents are applied. Prior to the addition of the anti-scaling agent, possible effects of these chemicals on the water treatment process were checked in lab studies.

Turbidity

To enforce subaquatic consolidation in the tailings, the tailings pond bottom was covered with dump material, which was dropped from ships. The dumping of the gravel-like material led to an increase in turbidity in the pond water. This was critical to the ion exchange operation. The exchange columns were blocked by the suspended particles, leading to the necessity of weekly resin washing.

The wash-out of soil from the tailings cover after heavy rainfall can cause problems in the lime precipitation technology as well. In most cases, the sedimentation in the SHP was enough to settle the suspended solids. But in some rare cases, the fine soil particles almost led to an overloading of the sedimentation basin in the water treatment plant. The only possible and fast reaction was the reduction of the throughput. In the long term, the fast grassing of the final tailings cover is the best choice.

Remediation process

As shown in figure 3, the maximum water treatment capacity was never used. To expect 100 % use of capacity is obviously not realistic. Experience from other treatment plants shows that 90 – 95 % of the maximum capacity is reachable. During the first operation period (1995 – 2003), the mentioned problems (algae, turbidity, other technical problems) led to the insufficient use of the capacity. From 2004 – 2010, the throughput was limited by radiation protection regulations. The area of uncovered tailings (distance between the water line of the pond water and areas covered with geotextiles only) was not allowed to be wider than 15 m in order to prevent dust abrasion. After decreasing the water level, the free tailings sludge had to be consolidated for several weeks until it became passable.

Cost optimizations

The first WTP consisted of two separate lines for residue immobilisation (one for arsenic and radium residues and one for uranium containing residues). The two different immobilisation lines were cost intensive. With the decision, that a further use of the uranium immobilisation product will not be feasible, the purpose of its separate immobilisation got lost. Facing the technical problems and in order to reduce the water treatment costs, the WTP was reconstructed in 2003. The technology was changed to lime precipitation.

After finishing of the pond water in 2012, the treatment capacity of 200 m^3/h was no longer necessary. Instead of operating the plant continuously with a low throughput, campaign operation was established after 2012. With some technical improvements it became possible to work in campaigns in winter, too. At the moment the plant operates one week and pauses for two weeks. Nevertheless, the oversized plant works quite uneconomically at the moment.

Long-term water treatment

Water treatment will be needed for at least 30 years after finishing the tailings remediation. Seepage waters from the dams will be the main sources of contaminated water. Effects linked to the pond water body (like increased turbidity or algae growth) will not occur anymore.

The first investigations in a long-term treatment technology started in 2006. At that time, the application of biological processes was seen as a favourable technology. However, experiments on uranium removal by bacteria or algae characeen showed insufficient results at the Helmsdorf site. Similar experiments and a long-term test of a wetland on other Wismut remediation sites failed as well. Therefore, wetlands and biological driven processes were excluded from further considerations on long-term water treatment in Helmsdorf. Both lime precipitation and the combination of ion exchange and adsorption technology were pointed out in a first feasibility study on long-term treatment at the site. Cost calculations for these two technologies showed economic benefits for a centralized treatment. On the basis of these first evaluations a pilot plant was built to test the combination of ion exchange and adsorbent technology on site. Results of complementary lab experiments on retention mechanisms [kassahun] were used to optimize the pilot experiments and significantly improved the resins uranium load capacity.

Figure 2 *Tailings pond Helmsdorf in 1991 (left) and 2014 (right)*

Table 2. Cost drivers of two different possible technologies for long term water treatment

Test #	Test pH	Advanced lime precipitation	ion exchange/adsorption technology
Chemicals	HCl	1491 t/a	419 t/a
	CaO	42 t/a	-
	FeCl3	111 t/a	-
	BaCl2	3 t/a	-
	cement	94 t/a	60 t/a
	Adsorbents	-	165 t/a
Power consumption		602 MWh	398 MWh
operators		5 h/d	1,5 h/d
Number of Technical devices (pumps, stirrers)		55	29

On the basis of long lasting monitoring data on seepage water quantity and quality predictions on further water treatment needs were made. Feasibility evaluation of the selected treatment technologies included auxiliary aspects like

- waste management
- use of different adsorbents and resin types (availability, supplier independence)
- influence of anti-scaling agents

By a seven years period of pilot plant testing, the stability of the ion exchange / adsorption technology was proven. The pilot plant data were used as input for further technical planning. Another effect was that personnel training on a new technology were performed by the pilot plant operation. Based on the convincing results, costs for a period of 30 years were calculated and compared to lime precipitation costs. There is a cost advantage for the ion exchange/adsorption technology. At least for the specific situation at Helmsdorf site the ion exchange/adsorption technology is linked to lower risks than the lime precipitation technology (increasing prices for chemicals, power consumption and technical failures). Table 2 compares different cost drivers of the two technologies.

On this basis, a new ion exchange / adsorption technology WTP is currently at the planning stage. The new WTP will operate from 2020 onwards. Unlike the existing WTP, the new plant will be remote-controlled from a WTP which is about 30 km away.

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