Sediments in affected river systems – lessons learned from WISMUT remediation

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Abstract

The remediation of the legacies of uranium mining in eastern Germany has been carried out by the state-owned Wismut GmbH (Wismut) since 1991. The status of remediation after approximately 30 years varies. While the majority of waste rock dumps have already been remediated and are undergoing aftercare, work on the industrial tailings ponds has not yet been fully completed. A long-term task remains the regulation of flooded mines and the water treatment at several sites.

Environmental monitoring includes all compartments, as surface and groundwater, air and solids. Monitoring of particulate matter as a preliminary stage to sediment takes place particularly in the area of discharges from the water treatment plants. However, other point and diffuse inputs are also recorded, which ultimately characterize the respective remediation site. For the investigation of suspended matter, sediment traps have been installed in sections affected by the remediation. Key analytical parameters along the water and sediment path are uranium and radium-226. In addition to this, arsenic, iron, nickel, zinc and total organic carbon are of interest depending on the specific sites. Over the 20-year observation period, the quality of these suspended solids is well described. The assessment of river quality is guided by both European (WFD 2000) and German (OGewV 2016) regulations, which for some elements (such as arsenic) focus exclusively on the quality of suspended solids or sediments.

Due to the transport of pollutants along the watercourses and the sediment composition as a long-term memory of river water chemistry, measures at water sources (as at Wismut) are of particular interest. The two case studies differ in terms of water body size and pollutant potential.

Keywords: Sediment trap, suspended matter, water quality, water treatment, river, uranium

Regional description and Methodology

All remediation sites of Wismut are located in the catchment area of the river Elbe (Fig. 1), which has its source in the Czech Republic, then flows through eastern and northern Germany into the North Sea.

The uranium deposits are located in the bedrock units (e.g. Erzgebirge), which are already characterized by a high variety of rock types and polymetallic deposits. This results in elevated geogenic background concentrations in water and sediments in the tributaries. Least 800 years, ore mining for various commodities has been carried out and, together with ore processing, has led to distribution of the elements into the environment. The contamination of the streams subsequently led to a shift of the contaminants to the river Elbe and the North Sea. The pollution situation of the Elbe and its tributaries has been substantially improved by a variety of measures since the beginning of the 1990s. The implementation of the sediment management concept adopted in 2013 is one key topic for the Elbe River Basin Community (FGG Elbe), on which regular reports are published. Besides the decline of mining and industrial production after 1990, the remediation of the legacies of uranium mining has also contributed to the improvement in the streams and rivers.

Small streams, which are considered as independent surface water bodies in Thuringia

Figure 1 *Site-wide Water Management*

are particularly affected by the effects of mining and remediation. For assessment under German law they are just as relevant as the larger river water bodies. For this reason, remediation measures and measures as part of water management concepts at the sites in these potentially sensitive areas are accompanied by monitoring plans that also include the analysis of freshly generated suspended matter in traps.

Depending on the morphology of the watercourse, "box-" or "cup-" type traps are installed. The traps are exposed for approximately one month (4 or 12 cycles per year), after which the collected suspended material is sieved to <63 µm and dried. Part of the fine fraction (< 63 µm) is used to prepare an aqua regia digestion for chemical analysis and another part is used to determine the particle size distribution and to determine the Ra-226 activity by gamma spectroscopy.

Principles of Wismut water management

Mine water management involves all measures for the collection and safe discharge of surface, seepage and ground water resulting from mining and processing operations with the aim of protecting surface and groundwater bodies in the surrounding area. This also includes the step of treating contaminated water before it is released into the environment. For Wismut, this is one of the particularly cost-intensive medium to long-term tasks. Information about water treatment plants (WTP) and their treated parameters is updated cyclically (Wismut 2024).

Due to the interactions between the aqueous and particulate phases, the treatment measures also give a benefit to the chemical composition of the suspended matter/sediments. This means that water management is also a key to sediment management – even without direct intervention into the watercourses.

Wismut Sites Ronneburg and Seelingstädt in the sub-catchment area of the Weiße Elster river

The Thuringian remediation sites Ronneburg and Seelingstädt negatively affect small water bodies within the catchment area of the Weiße Elster river (Fig. 2).

The sampling and analysis of suspended matter in Thuringia at currently twelve points (traps) are conducted to record the suspended matter composition in respect of uranium and further metals, arsenic and radionuclides in the streams and rivers affected by the remediation process. The assessment is carried out with regard to possible influences in connection with land remediation and reclamation, opencast mine remediation, the flooding of the Ronneburg mine and the discharge of treated water from the Ronneburg and the Seelingstädt WTP.

The flooding of the Ronneburg mine began in 1998. The approximately 17 million m³ mining cavity in the southern (partial) flooding area Ronneburg is of particular interest for the close-by tributaries. Discharge water is collected in a newly constructed drainage system in the morphological deepest area of the Gessental valley. It was planned to collect all water outflow with this system avoiding discharge into aquifers and surface streams.

During the final flooding ("mine water rebound") phase between 2006 and 2011, it became clear that the drainage system was to small to catch all mine water outflow and escaping mine waters (rock and soil passage) appeared on the surface of the Gessental floodplain and entered the surface water of the close-by tributaries. To manage the water outflow various measures were implemented as sealing of hydraulic connections by former boreholes and mining shafts as well as setting up a central deep well to pump water from the mine workings. The aim was to lower the mine water level slightly, but this does not change the general, complete flooding of the mine. For the main discharge area Gessental, it could be shown that apart from a release of contaminants from the flooded mine initially substantially higher concentrations can be attributed to the leaching of the near-surface oxidation zone located directly in the downstream of the mine. In addition, there is a stored inventory of potential contaminants originating from the former waste rock dumps in the upper soil layers (Baacke et al. 2015).

During a temporary lowering of the mine water level in the Ronneburg mine field from the beginning of 2014 to the beginning of 2017, further work was carried out to optimize the groundwater collection system in the Gessental valley. When the constant flooding level was reached in 2018, the core remediation at the Ronneburg site was completed. Depending on the mine water inflow and the mine water collected the water level is managed in a 2-m-water-level-range (operating storage volume). In 2022, a hydraulic test was carried out on the above buffer reservoir of the (partial) Ronneburg mine. The mine water level was briefly raised by about 3 m in order to verify the strategy and the technical requirements for controlling the mine water level.

For uranium, the described release from the oxidation zone during the mine water rebound can be demonstrated on the basis of the uranium concentrations in the Gessenbach water (Fig. 3). The uranium increase in the water phase led to an increase in the particulate matter a short time later,

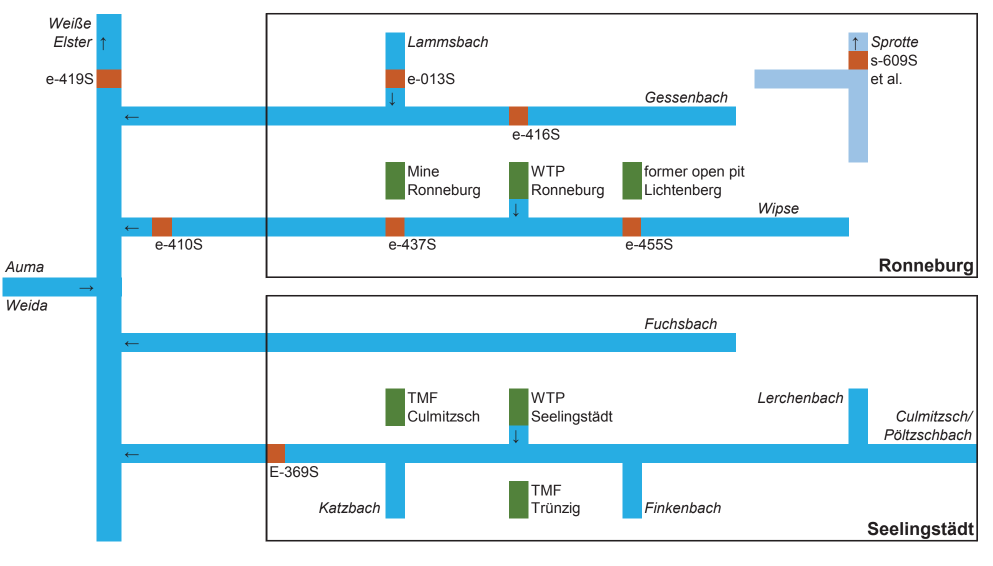

Figure 2 *Overview of the sites Ronneburg and Seelingstädt with their suspended matter sampling points (brown squares)*

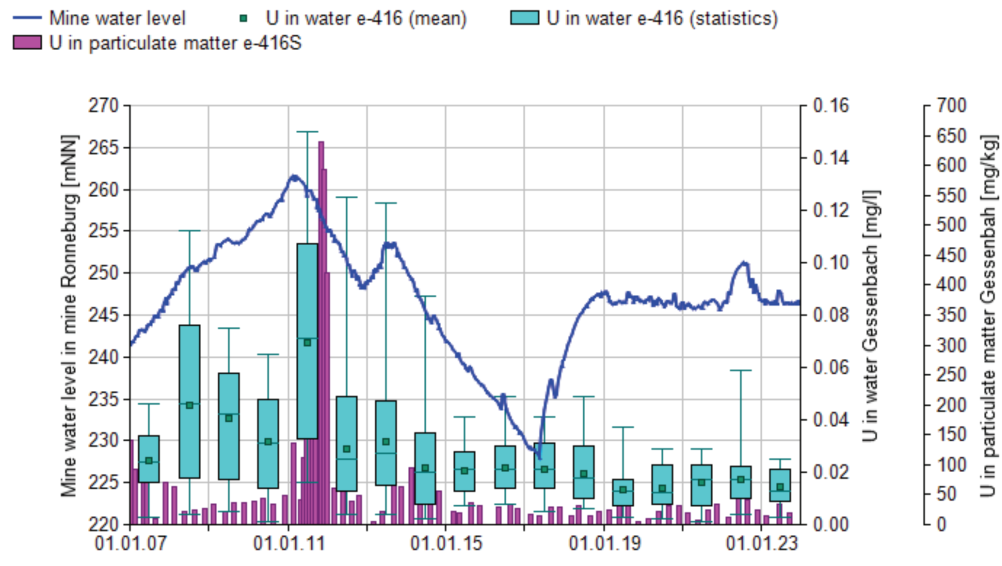

Figure 3 *Uranium concentrations in water and suspended particulate matter in the Gessenbach stream in context of mine water level in the southern mine part Ronneburg*

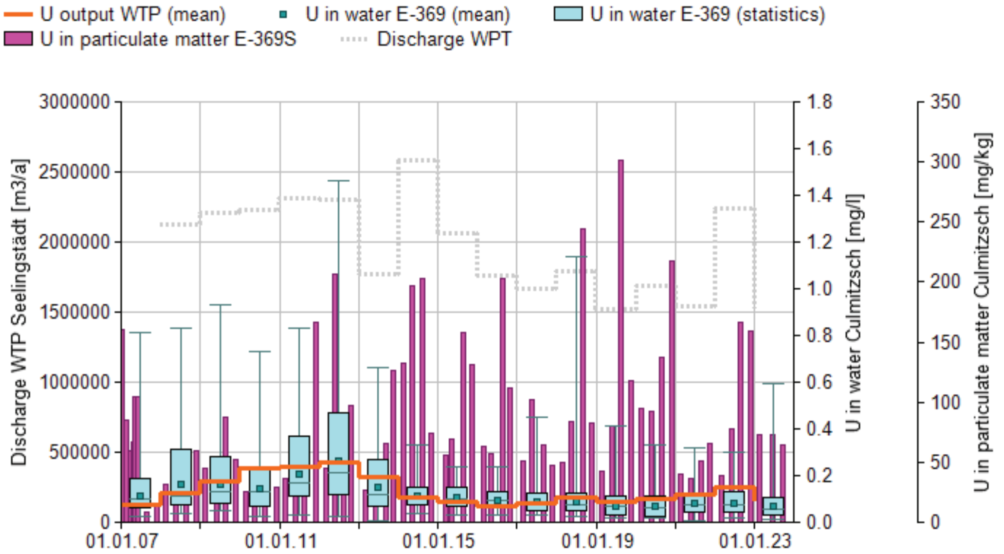

Figure 4 *Uranium concentrations in water and suspended particulate matter in the Wipse stream in context of treatment conditions (discharge and mean uranium concentration) of WTP Ronneburg*

meaning that a transfer into the sediment took place. This effect is not the same for all elements, but depends on the amount released, the environmental conditions and the respective preference of the elements for particulate bonding. All mine and contaminated seepage water collected in connection with the Ronneburg mine water rebound are treated in the WTP Ronneburg and then released into the stream Wipse.

***Table 1** Mean concentrations of selected elements in particulate matter in Thuringia (2022; n = 4)*

Point / Location	As [mg/kg]	Cr [mg/kg]	Cu [mg/kg]	Ni [mg/kg]	Zn [mg/kg]	U [mg/kg]	Ra-226 [Bq/kg]
e-416S Gessenbach	29	57	**167**	119	351	38	276
e-437S Wipse	**51**	55	**195**	141	239	150	309
E-369S Culmitzsch	38	57	75	63	338	110	225
E-419S WE	28	103	111	95	**829**	12	150
OGewV 2016	**40**	**640**	**160**	–	**800**	–	–

The maximum mine water level in 2011 (see Fig. 3) was accompanied by a maximum of the uranium concentrations from the WTP, which were subsequently deposited in the water and suspended solids of the Wipse stream (Fig. 4). These concentrations have been falling since 2013. After 2018, when the specified mine water level was reached, the quantities to be treated also decreased. With comparable treatment results regarding uranium, the effects on the receiving water also decreased.

The residues from the Seelingstädt ore processing plant were deposited into the two industrial tailings management facilities (TMF) Trünzig (1,2 km2 basin surface, 19 million m3 tailings in two basins) and Culmitzsch (2,4 km2 basin surface, 85 million m3 tailings in two basins) located at sites of former open cast mines. The deposition of tailings continued from 1960 to 1990. The remediation of both TMFs was carried out as in-situ dry-decommissioning. The remediation of TMF Trünzig was completed in 2013, for TMF Culmitzsch this is planned for 2028 (Metschies et al. 2015).

Water management at the Seelingstädt site includes the collection of contaminated surface water, seepage water and groundwater using drainage systems and wells within the tailings and in the surrounding area. Nevertheless, there is a small outflow of seepage water also to the Culmitzsch/Pöltzschbach watercourse. The treated water from the WTP Seelingstädt also discharges into that small receiving stream. The WTP Seelingstädt is in operation since 2001. The element concentrations in suspended particulate matter of the Culmitzsch/Pöltzschbach stream are stable with little fluctuation over time.

In comparison to the legal requirements (OGewV 2016), there are only minor exceedances of arsenic and copper in the streams for suspended matter at the Thuringian locations (Table 1). The cause of the high zinc contents in the Weiße Elster (WE) river lies in its upper reaches.

Wismut Sites Schlema-Alberoda and Crossen in the Zwickauer Mulde catchment area

The Saxon sites Schlema-Alberoda and Crossen influence only one small water body (Schlema) within the catchment area of the river Zwickauer Mulde and the Zwickauer Mulde itself (Fig. 5). In the Zwickauer Mulde, at the entrance to the Schlema-Alberoda remediation area, there is considerable pre-pollution with metals and arsenic from the upper catchment area, which is naturally mineralization rich and hosts numerous ore deposits (Table 2). Influences from the remediation area can only be detected to a limited extent for these elements in the suspended matter, as the effects of dilution and interactions between the compartments take place simultaneously along the flow path. Tributaries such as the Schlema stream are monitored for pollution from old mines (e.g. via the Marcus-Semmler adit). Details on sources and their load portions are summarized in Greif et al. (2023).

The construction of the WTP Schlema-Alberoda led to a substantial improvement in water and suspended matter quality in the Zwickauer Mulde river (e.g. uranium in Fig. 6), which also extends beyond the Crossen site downstream. Wismut measures are therefore of supra-regional importance for the river basin. Between the Schlema-Alberoda and Crossen site a dilution takes

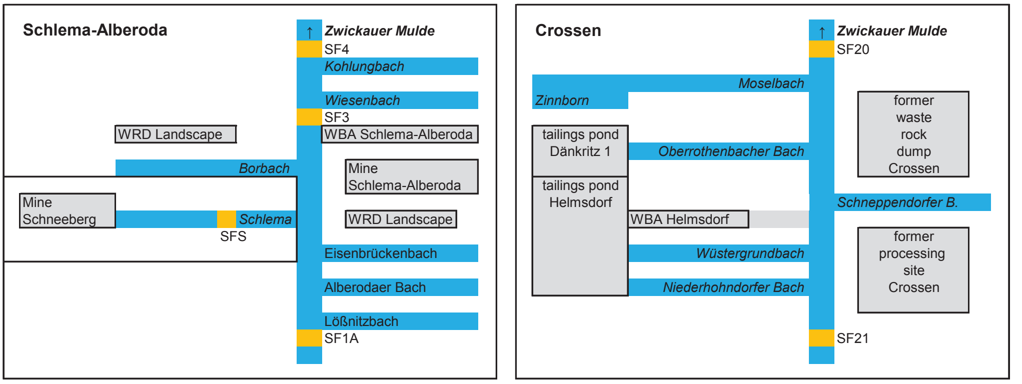

Figure 5 *Overview of the Schlema-Alberoda and Crossen sites with their objects and suspended matter measuring points (brown squares)*

Table 2 *Mean concentrations of selected elements in particulate matter in Saxony*

Point / Location	As [mg/kg]	Cr [mg/kg]	Cu [mg/kg]	Ni [mg/kg]	Zn [mg/kg]	U [mg/kg]	Ra-226 [Bq/kg]
SF1A (n=12)	**228**	78	**366**	745	**1670**	33	399
SF4 (n=12)	**206**	68	**235**	298	**1340**	88	400
SF20 (n=4)	**142**	–	–	–	–	62	356
SF21 (n=4)	**157**	–	–	–	–	73	390
OGewV 2016	**40**	**640**	**160**	**–**	**800**	**–**	**–**

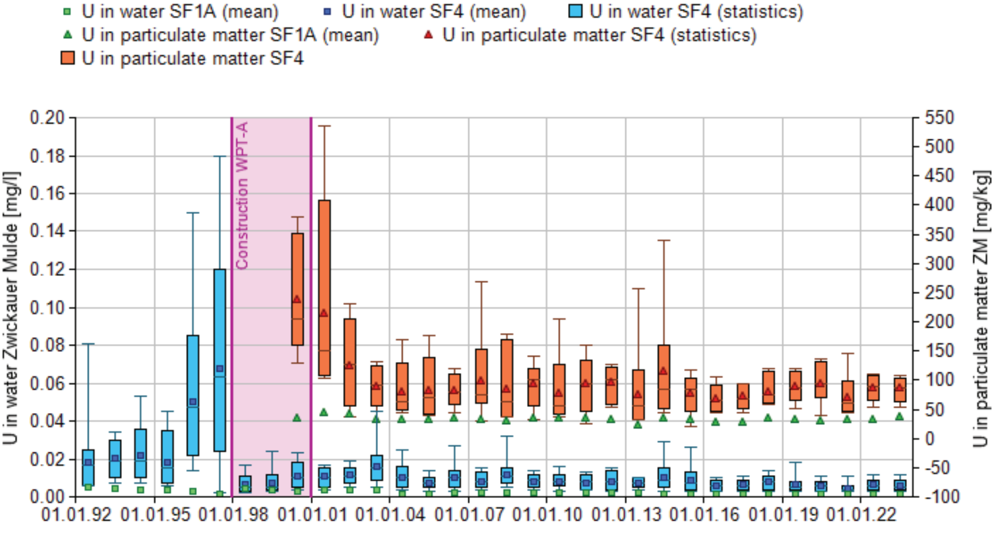

Figure 6 *Uranium in water and particulate matter of the Zwickauer Mulde river at the Schlema-Alberoda site*

place (Table 2). The influence of the largely completed remediation of the Crossen site on the quality of the ZM is low and essentially still detectable for the element uranium.

Conclusions

The remediation of uranium mining legacies and especially the operation of water treatment plants by Wismut prevent pollutants from entering the respective river section in the fluid phase. The trans-regional importance results from the fact that there is a storage of elements in the solid phase deposited at the river bottom which is then spread due to the sediment transport along the rivers. Thereby, management of surface-, seepage- and ground water thus also represents a sediment management within the catchment area.

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