Former mining activities influence Uranium concentrations in the Elbe river near Magdeburg

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Abstract. This paper presents data of dissolved and total uranium concentrations after the 2002 flood event, at a flood in spring 2003, and during an extreme low water period 2003 in the river Elbe. In addition, data from several Saale river tributaries are evaluated. The results reveal the remaining pollution potential in the Mansfelder Land catchment that requires the development of remediation strategies.

Introduction

Transport and fate of uranium (U) in the Elbe river are not integrated in the current water quality monitoring programs. As a result of the 2002 flood event in the Elbe and Mulde rivers – that triggered flooding and destruction of former mining areas – U concentrations in the Elbe river are now in the scientific focus.

Samplings were carried out in the Elbe river at different hydrological conditions at Magdeburg monitoring station. This sampling site is also part of the measurement programme of the International Commission for the Protection of the Elbe (IKSE/MKOL) and situated on the left bank at river km 318 (Fig. 1). The water quality here depends on inputs of upper Elbe stretches from the Czech Republic and the Dresden industrial region as well as of the polluted tributaries Mulde and Saale. The confluences of the rivers Mulde and Saale are 59 km and 27 km upstream of the sampling site on the left bank. Both tributaries were affected

by former mining activities. However, under normal discharge conditions, data of the sampling station represent the pollution situation of the middle Elbe.

At low water flow the input of the Saale river to the water quality at this site is increasing, due to the high salt load of the Saale which is detectable at the left side of a long stretch of the river Elbe (about 100 km).

To assess the origin of the Saale U pollution, several of its tributaries were investigated (Fig. 2).

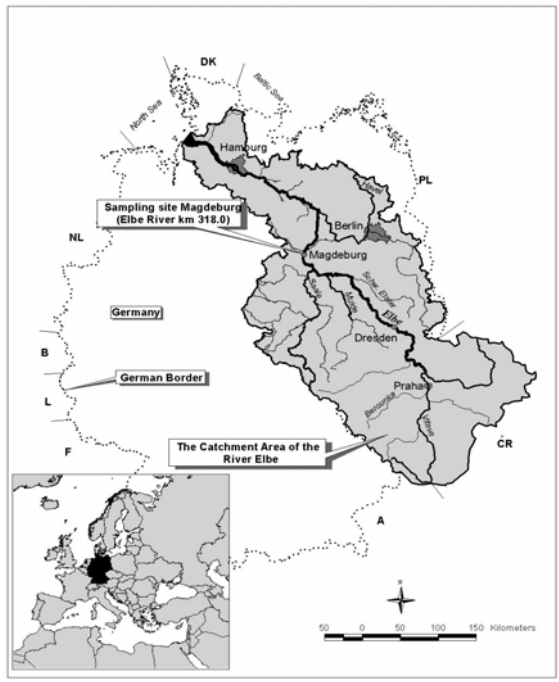

Fig. 1. Sampling site Magdeburg with main tributaries of the river Elbe (Map: O. Büttner, UFZ Centre for Environmental Research Leipzig-Halle).

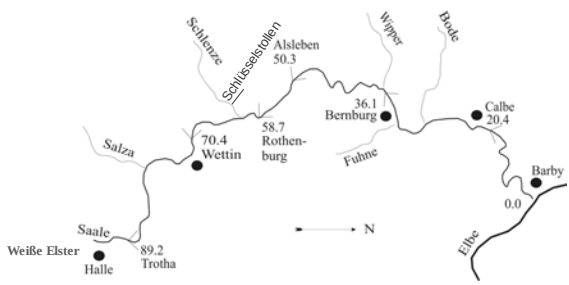

Fig. 2. Lower Saale river stretch with main tributaries.

Methods

The monitoring of the water quality of the Elbe at river-km 318, left side was based on a daily sampling during the extreme events 2002 and 2003 as well as a weekly sampling in the remaining time. From June to August 2004, a screening of the Saale tributaries Weiße Elster, Salza, Schlenze, Wipper, Fuhne, Bode was carried out above their mouths (seven samplings) into the river. Due to the importance of the input of the drainage gallery Schlüsselstollen into the Schlenze a diurnal investigation was performed (September 2004) in the outlet of the gallery as well as above and below the mouth of the gallery into the river.

The content of suspended particulate matter (SPM) was measured according to German Industrial Standards (DIN 38409 part H2). Dry weight (dried for two hours at 105°C) and loss on ignition (ignited for four hours at 500°C) were determined from sample water filtered onto Whatman GF/F glass fibre filter (vacuum filtration method, -200 mbar).

Physico-chemical parameters (pH, water temperature, conductivity, dissolved oxygen, redox potential) were measured in situ.

U was analysed in non-filtered as well as filtered (0.45 µm syringe filters, Minisart, non-pyrogenic) water samples. After microwave assisted digestion with HNO_3/H_2O_2 of the non-filtered samples and acidification of the filtered samples with HNO_3, these were analysed by ICP-MS (Agilent instrument). The detection limit was 0.5 µg/l.

In this paper, U concentrations in non-filtered samples are referred to as "totals", while element contents from filtered samples are referred to as "dissolved". "Particulate" concentrations are calculated from the difference between "total" and "dissolved".

Results and discussion

After a "centennial" flood in August 2002 (originated in upper Elbe and Mulde catchment) and a flood in January 2003 (originated in Saale catchment), the river Elbe saw an extremely low runoff period from June/July until December 2003. The changes of uranium loads with varying discharge in the river Elbe at Magdeburg monitoring station are shown in Fig. 3. The flood of 2002 destroyed built-up and former mining areas and caused a widespread erosion and the relocation of soils and river sediments. Unlike the ore and companion elements arsenic, lead and copper, the concentrations and loads of which were significantly increased in August 2002 (Baborowski et al. 2004), and the uranium load was higher during floods that originated in the Saale catchment (November 2002, January 2003). The data reveal some remaining uranium pollution sources from former mining areas in the Saale catchment (Gera-Ronneburg ore mining area, Mansfelder Land copper schist area). This assumption is supported by increasing U concentrations at low discharge, as shown in Fig. 4.

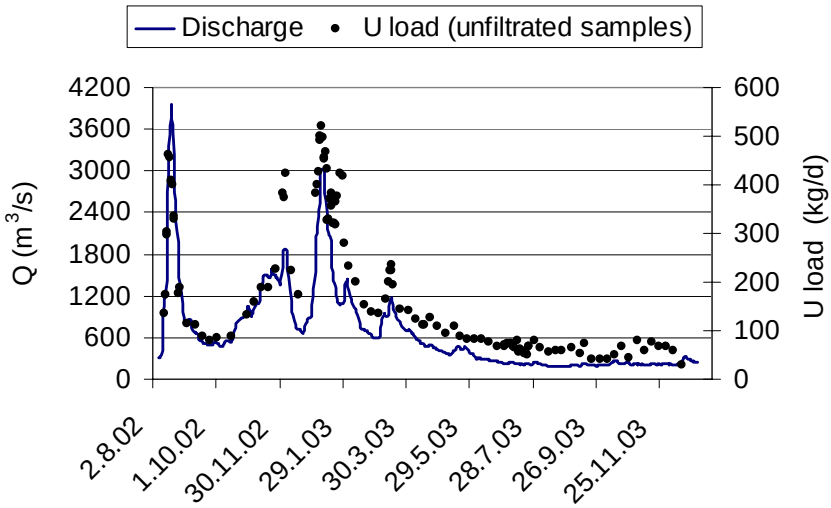

Fig. 3. Uranium load and discharge between August 2002 and December 2003 in the river Elbe at river-km 318, left bank (discharge values: daily averages, water level gauge river km 326.6)

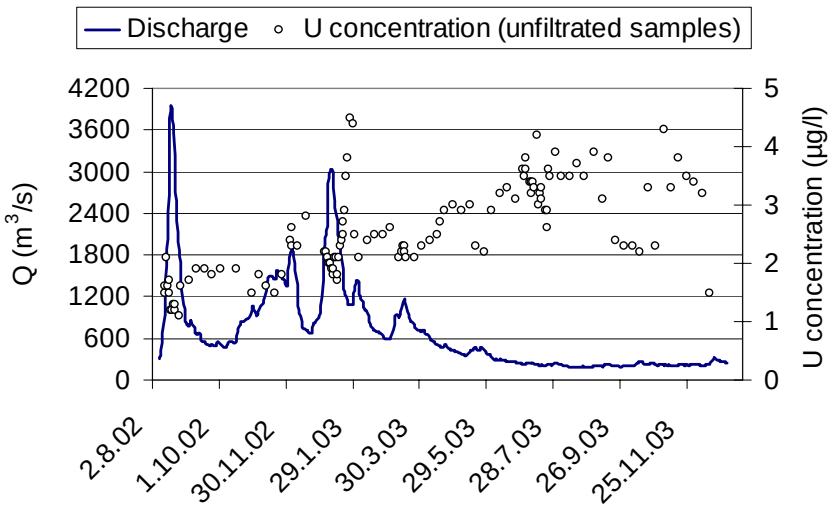

Fig. 4. Total uranium concentrations and discharge between August 2002 and December 2003 in the river Elbe at river-km 318, left bank (discharge values: daily averages, water level gauge river km 326.6)

Results of water quality measurements during low water periods present higher impact of tributaries to the main stream due to changes in mixing processes. Increasing U-concentrations developped with conductivity (Fig. 5). This clearly reflects inputs of the river Saale especially of the former mining areas in the Saale catchment whose rocks are characterised by high salt content. Increased concentrations of trace elements during long time low water periods were less important to the annual load but to the ecosystem.

In contrast to the correlation of the dissolved U concentrations and conductivity, particulate uranium showed no evident relation to particulate matter, especially to the organic content as demonstrated by loss on ignition (Fig. 6). Relating to the temporal variability of particulate concentrations, the expected increase in the vegetation period, due to the incorporation or attachment of dissolved uranium to phytoplankton, could not be shown.

However, the results of the measurements at Magdeburg monitoring station raise the question of the participation of the tributaries in the lower Saale catchment on their U pollution. An overview of the variation of U concentrations as well as the mean values of conductivity and SPM is given in Table 1. The results varied strongly between the tributaries. Due to difficulties to obtain actual discharge values representing the sampling locations, the table contains daily averages of discharge near the mouth of the tributaries. The discharge values are data of water level gauges provided by the Saxony-Anhalt State Company for Flood Control and Water Management of the stations Oberthau (W. Elster), Baalberge (Fuhne), Zappendorf (Salza), Friedeburg (Schlenze), Großschierstedt (Wipper) and Hadmersleben (Bode). The value of the Schlenze covered a fixed estimated value of 0.3 m^3/s (based on http://www1.mw.sachsen-anhalt.de/gla/infos/inggeo/seekonferenz.htm) for the outlet of the gallery water.

Table 1. U concentrations in tributaries of the lower part of the river Saale (n=7, June to August 2004).

Concentration (µg/l)	Weiße Elster	Fuhne	Salza	Schlenze	Wipper	Bode
Minimum	3.0	11.0	9.7	54.0	2.6	1.4
Maximum	5.0	15.0	17.0	66.0	5.6	3.2
Mean	4.1	12.4	14.5	58.1	4.3	2.4
Median	4.7	13.0	14.0	56.6	4.8	2.5
Conductivity (mS/cm)	2.3	1.9	3.2	36.4	1.2	6.4
SPM (mg/l), mean	16.0	5.9	18.4	19.4	13.9	5.0
Q (m^3/s) Minimum … maximum	9.13 … 22.4	0.472 … 1.1	0.592 … 0.918	~ 0.39 … ~ 0.44	0.482 … 1.5	6.36 … 7.95

The lowest total U-concentrations were found in the Bode river, the highest ones in the river Schlenze. Beside uranium the highest salt concentrations in the Schlenze were measured, too. The dissolved fraction of the total uranium (data not shown) varied from 80 to 100%.

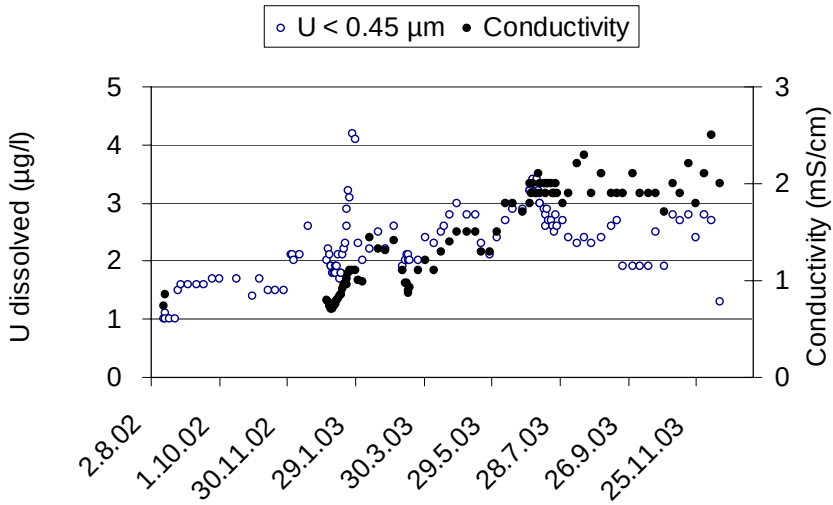

Fig. 5. Dissolved U concentrations and conductivity in the river Elbe at river-km 318, left bank (August until December 2002 no conductivity values available).

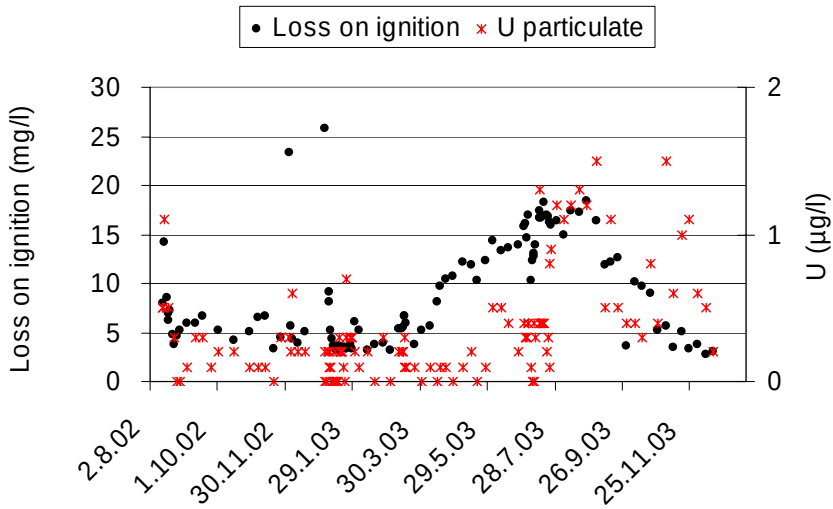

Fig. 6. Particulate U concentrations and loss on ignition of SPM in the river Elbe at river-km 318, left bank.

Results of diurnal investigations of the Schlenze river are given in Fig. 7. It could be shown that the water quality of the Schlenze depends on the input of the drainage gallery Schlüsselstollen that drains part of the Mansfeld copper schist area. The diurnal investigations at the outlet of the gallery showed low fluctuating, mainly dissolved transported U concentrations related to stable physico-chemical conditions. This indicates groundwater influence on the gallery waters.

The discharge of the gallery water is approximately 3 times higher and accompanied by 3 to 4 times higher U concentrations as compared with the discharge and U concentration of the Schlenze above the gallery outlet. Due to the short distance (about 3 km) between the outlet and the mouth of the Schlenze into the river Saale the quality of the outlet water has a decisive influence on the input of the Schlenze into the Saale.

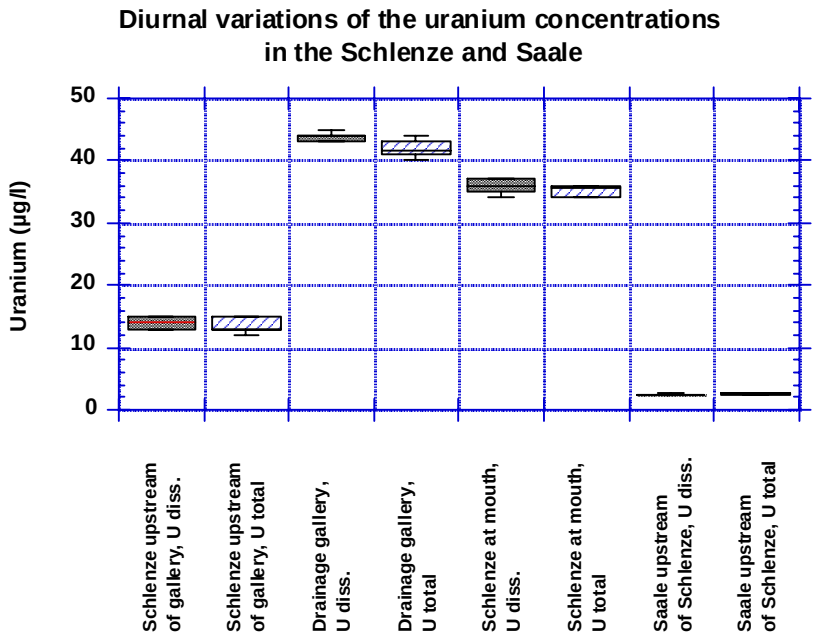

Fig. 7. Diurnal variation of the dissolved and total U concentration (9./10. September 2004, n=12) at the sampling locations Schlenze, above and below the mouth of the drainage gallery into the river Schlenze, as well as in the gallery outlet, and in comparison in the river Saale above the mouth of the Schlenze.

Conclusions

Using uranium as a tracer, the assessment of flood and low discharge conditions revealed a higher influence of the Saale input to the Elbe river below Magdeburg monitoring station, left side as compared with the Mulde river. The screening of the Saale tributaries indicated a remaining pollution potential in the Saale catchment. The U-concentrations in the tributaries, originating from the Mansfelder Land catchment (Salza, Schlenze), exceeded those from the Weiße Elster river, which is influenced by former mining activities in the Gera-Ronneburg ore mining area. The Schlenze acts as point source for uranium in the Saale due to the relatively constant input of the drainage gallery Schlüsselstollen. Although the load is low compared to the Weiße Elster, and the concentrations will be diluted by mixing with the Saale water, the concentrations considerably exceed existing thresholds. The protection aim for surface water is 3 µg/l (Report BRD 2003). WHO guidelines for drinking water propose an U limit of 2 µg/l (Reimann and Banks 2004). For the aquatic ecosystem it is of importance that the dissolved fraction dominated the total content of uranium. Therefore, the remaining pollution potential from former mining activities in the Mansfelder Land requires the development of remediation strategies.

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