Development of water-borne radioactive discharges at WISMUT and resulting radiation exposures

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Abstract. Since 1989, collected discharges of uranium loads via the water pathway have dropped from a total of 27.5 tonnes to less than 3 tonnes in 2004. Commissioning of modern water treatment plants has greatly contributed to this achievement. Resulting site-specific effective doses to the population are significantly below 1 mSv/a. However, diffuse discharges of contaminated seepage or percolation waters from tailings ponds may cause doses in the order of 1 mSv/a. Capping operations are instrumental in reducing the diffuse discharge of radioactive effluents via the water pathway to a reasonably low level.

Introduction

The radiological situation prevailing in 1991, immediately after the termination of uranium ore mining and uranium processing in East Germany, was marked by the discharge of radioactive substances carried by water both into receiving streams and underground. Such discharges contributed significantly to public exposure. Ever since the state-owned company Wismut GmbH initiated remediation procedures, the volume of discharges was continuously reduced. Furthermore, the changing of nature of discharge and its comprehensive monitoring helped to systematically bring down public radiation exposure at former mining sites in Thuringia and Saxony.

The development of discharges, of radiation exposure due to radioactively contaminated waters, as well as avenues of reducing this exposure further are discussed below.

Classification of water-borne emissions

In the following, a clear distinction is made between:

1. Controlled discharge into receiving streams or underground: Typically, such waters are collected and monitored for volume and quality. Discharge is from specific hydraulic structures (drainage structures) or from water treatment plants.
2. Diffuse leakage of seepage and percolating waters into ground and running waters: Quantity and to some extent the quality of such waters can only be evaluated by modelling. Their sources are infiltration waters percolating through mine dumps, tailings ponds, and mine workings.

Development of controlled water discharges and of resulting radiation exposures

The development of controlled radioactive discharges in terms of the radiological main components uranium and Ra-226 together with the quantities of discharged waters is illustrated by Fig. 1.

The development of pumped mine waters discharged from the Ronneburg, Aue, Gittersee, and Königstein mine fields (flooding of mines involving treatment of pumped flood waters) has a decisive impact on waste water quantities. The drop in concentration levels in water discharges is reflected by a more significant drop in the loads released or the activities discharged, respectively, in comparison with the decrease in water quantity. This is the result of powerful water treatment plants

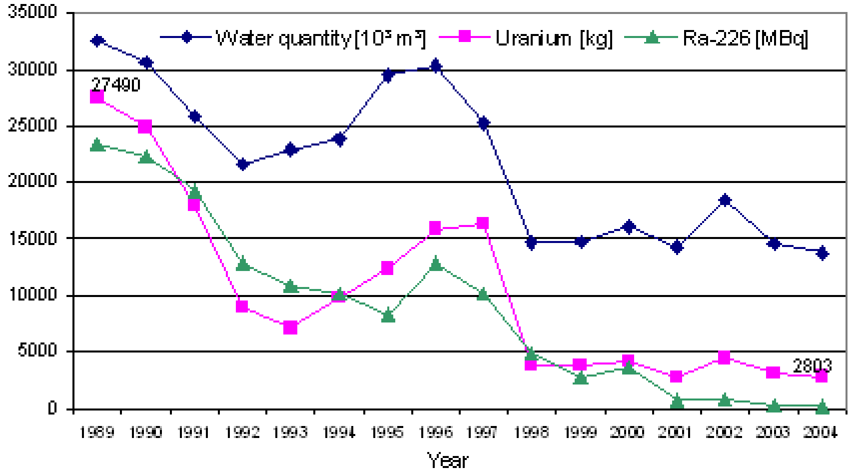

Fig. 1. Development of radioactive discharges from 1989 to 2004.

(WTP) coming on line. Table 1 provides a picture of water treatment plants operated by WISMUT, their performance parameters, as well as permitted discharge standards.

In addition to treated waters, controlled discharge also includes untreated waters. In the majority of cases, feed waters are made up of collected seepage from mine dumps for which no conditioning in terms of (some local) treatment is yet available and which therefore have to be discharged into receiving streams of appropriate size. Peak concentration levels are up to 5 mg/l for U_{nat} and 0.2 mBq/l for Ra-226. Compared to the quantities of water discharged from WTPs, the amount of untreated but controlled discharges is negligible (order of 5 %). As average concentrations of radio-nuclides in these waters are normally of the same order of magnitude as in the case of WTP-treated waters, the same applies for discharged activities.

Discharge-induced radiation exposures are insignificant. The following section exemplifies the order of magnitude of effective doses to the public which may attain in case where 100 % use is made of discharged waters showing concentration levels equal to permitted discharge standards (conservative assumption). As a rule, however, straightforward use of discharged waters is improbable or ruled out when properly collected. Upon discharge into receiving streams, the collected waters are by majority of cases diluted. The magnitude of the mixing ratio ranges from 1 : 20 (discharge from the Aue WTP into the Zwickauer Mulde river) up to 1 : 2000 (Königstein WTP into the Elbe river). Only at the Seelingstädt site, during periods of low water flux of the receiving Culmitsch creek the ratio comes close to one.

Table 1. Survey of water treatment plants operated by WISMUT and of discharge waters.

Site	Capacity [m³/h]	Type of feed water	Main radiological component [a]	Permitted discharge standard U_{nat} [mg/l]	Ra-226 [Bq/l]	U_{nat} loads [t/a]
Aue	1000	Mine water	5 mg/l U_{nat}	0.5	0.4	4,4
Pöhla	130	Mine water	2.5Bq/l ^{226}Ra	0.2	0.3	0,175
Helmsdorf	250	Supernatant w.	10 mg/l U_{nat}	0.5	0.2	0,88
Königstein	650	Mine water	100 mg/l U_{nat}	0.3	0.4	1,7
Seelingstädt	300	Supernatant w. Seepage	2 mg/l U_{nat}	0.3	0.2	0,63

[a] Level order of magnitude

Diffuse release of radioactive substances and related radiation exposures

The uncontrolled, i. e. diffuse release of radioactive substances and the related radiation exposures are exemplified by the situation at the Trünzig Tailings Management Area (TMA). With its content of radioactive and chemico-conventional uranium processing residues (volume of 19 million m^3, area of 120 ha to be covered), the Trünzig TMA is one of the large-size facilities of the Seelingstädt site. The environmental assessment performed in 2000 to evaluate the status of the site at that time (in 2000 the facility was partly regraded and provided with an interim cover) concluded that, in addition to 114.000 m^3 of seepage emerging near the surface and being collected and fed to the Seelingstädt WTP, some 69.000 m^3 of percolating water would propagate either to the ground water or disperse in the receiving streams (Lerchenbach, Finkenbach creeks) (Wismut, 2000). Uranium levels observed in groundwater flowing downstream from the tailings deposit were up to 1 mg/l close to the facility. This allows a rough estimate of an annual uranium load of about 100 kg being released from the Trünzig TMA.

Diffuse groundwater flow to the receiving streams is reflected in increased nuclide levels in surface waters. Table 2 shows findings of water samples taken from the Lerchenbach creek north of the Trünzig TMA and analysed for nuclide levels. Nuclide levels as well as the nuclide vector where uranium nuclides are dominant are in the range of levels measured near tailings management areas elsewhere.

Fig. 2 and 3 below illustrate the resulting radiation exposures likely to follow the use of water of such quality. While the exposure scenarios are conservative, they cannot be fully ruled out. All computations are based on Berechnungsgrundlagen Bergbau, the German guidelines for calculation of effective doses at mining sites (BMU,1999). Water use assumptions made included 100 % consumption as drinking water as well as 100 % use for food production (consumption of fish taken from the Lerchenbach creek, cattle watering, irrigation of field and garden crops; amounting to 25 % satisfaction of annual consumption rate). Fig. 4 exemplifies for two exposure pathways the contribution of the various nuclides from the uranium-radium decay chain to the effective dose of the local public.

Table 2. Radionuclide levels [in Bq/l] established for water in the Lerchenbach creek north of the Trünzig TMA.

U-238	U-234	Th-230	Ra-226	Pb-210	Po-210	U-235	Pa-231	Ac-227
5.2	6.1	0.17	0.02	0.025	0.025	0.24	0.015	0.015

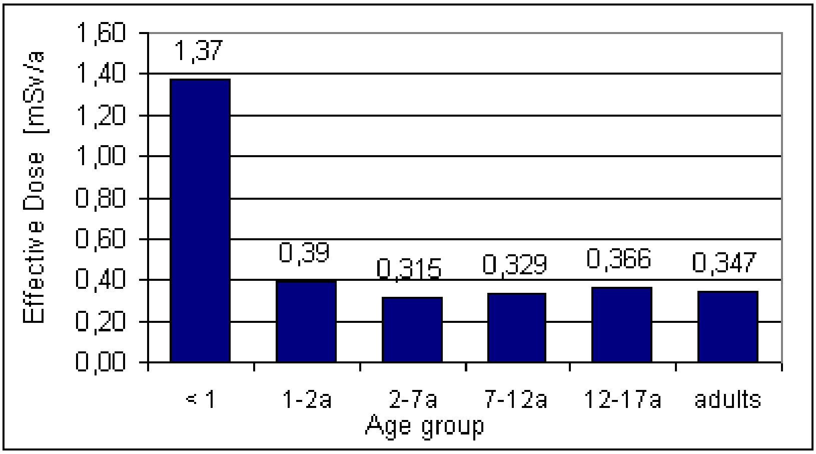

Fig. 2. Annual effective dose resulting from consumption and use of water taken from the Lerchenbach creek for all age groups to be considered; contribution from all exposure pathways taken into account (see Fig. 3 in detail).

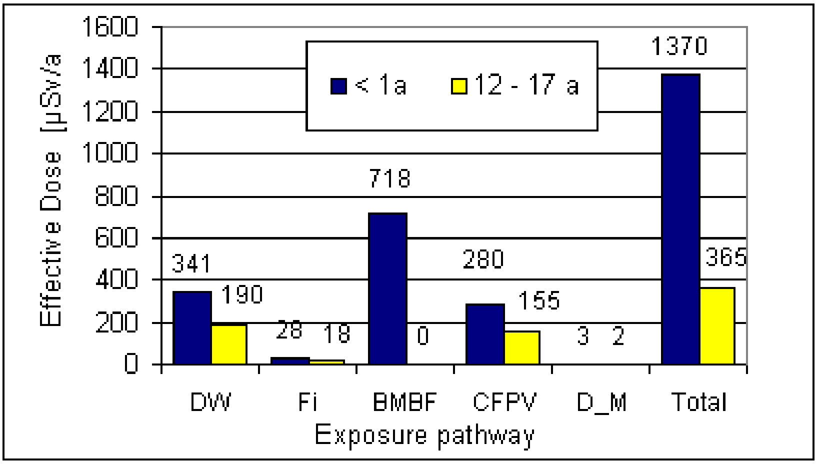

Fig. 3. Effective annual dose resulting from consumption and use of water taken from the Lerchenbach creek; contributions from the exposure pathways taken into account for age groups [< 1 a] and [12 -17 a]; (DW – drinking water; Fi- fish consumption; BMBF– consumption of breast milk / baby food prepared with the water; CFPV – consumption of locally produced cereals, fruit, potatoes, vegetables).

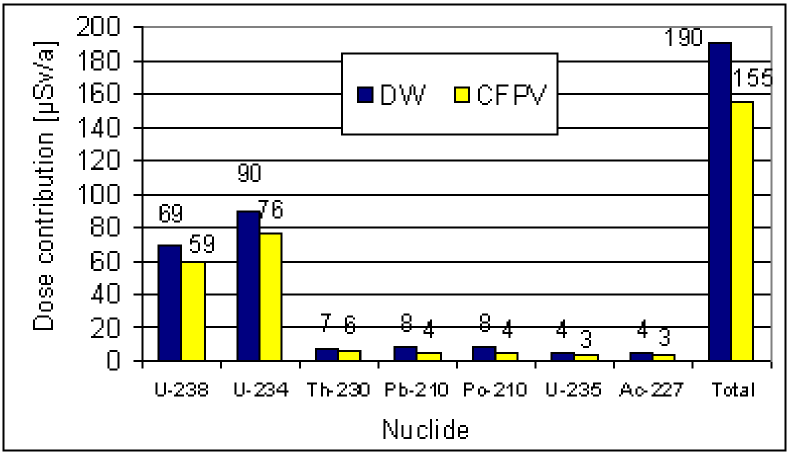

Fig. 4. Effective annual dose resulting from consumption and use of water taken from the Lerchenbach creek; contributions from nuclides for age group [12 - 17 a], consideration of the exposure pathways DW- drinking water and CFPV – consumption of locally produced cereals, fruits, potatoes, and vegetables, respectively.

Some general conclusions may be drawn beyond the example considered:

1. Given the characteristics of waters encountered in the vicinity of abandoned WISMUT sites (with mostly neutral or acidic pH), the nuclide vector is typically determined by the nuclides U-238, U-234, and U-235. Predominance of these nuclides is that great that they account for the major part of the effective dose, notwithstanding relatively low dose coefficients as compared to Po-210 or Ac-227.
2. When applying standard scenarios of Berechnungsgrundlagen Bergbau (BMU, 1999), giving in particular full consideration to the drinking water path, the highest individual doses will be to the small child up to one year of age. Thereby, the pathways DW - drinking water, and BMBF - consumption of breast milk and baby food prepared with the water, respectively, are dominating the level of effective dose in this age group.
3. Overrun of the guidance value of 1 mSv/a is most likely for age group [< 1 a] when applying standard scenarios. However, exposure pathway analyses performed as part of environmental assessments show that effective doses due to the aquatic pathway are as a rule less than 1 mSv/a.
4. Consideration of site-specific exposure scenarios instead of standard scenarios and consumption rates of a reference man according to (BMU, 1999) when performing exposure pathway analyses almost exclusively leads to effective doses due to the aquatic pathway of significantly less than 1 mSv/a.

Evaluation of and possibilities to reduce discharges and releases of radioactive substances from abandoned WISMUT sites

With the continuation of water treatment, radiation exposure due to discharges will also be kept low in the future. According to model predictions, water treatment plants will have to be operated for another decade, in some cases even for up to 20 years. It is anticipated that concentration levels in feed waters to WTPs will have sufficiently faded away by then to allow alternative treatment methods (passive procedures) or to discontinue water treatment altogether.

Uncontrolled leakage of contaminated waters from TMAs and mine dumps as well as from mine workings is being reduced as rehabilitation advances. Mines are flooded in a controlled manner, involving treatment of pumped mine waters. Tailings management areas and mine dumps left in place are being capped. Capping of the tailings areas is done with the primary objective of denying access and assuring their long-term stabilisation and providing long-term geochemical stability of their inventory. In the case of mine dumps, capping is done in a manner to minimise radon exhalation in addition to reduce the leakage of contaminated waters.

By their levels in the order of 1 mSv/a, individual doses as a result of water discharges as outlined in the above section do not suffice to constitute the sole basis for the optimisation of rehabilitation measures. The immense costs involved in the rehabilitation of TMAs in particular can only be justified by a multitude of factors considered in an optimisation process (long-term enclosure, geostability, geochemistry, impact by conventional contaminants). The radiological impact on the environment via the aquatic pathway constitutes an essential aspect in that effort, but is one among others.

References

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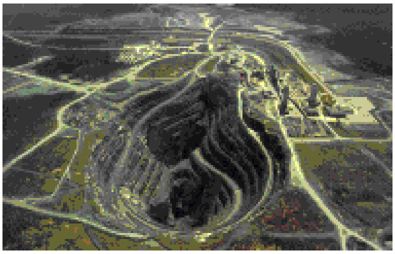

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