

Rehabilitation of Former Uranium Mining and Milling Sites in Germany (WISMUT Sites) - A Health Physicists Perspective - 10091

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ABSTRACT

Radioactively contaminated mining sites are characterised on the one hand by low levels of radioactivity in the residues and environmental media (LLW - Low Level Waste), and on the other hand by big amounts of contaminated material as well as by large areas of contaminated land. Within the WISMUT Project, dedicated to rehabilitate the legacy of the East German uranium industry, proper management of LLW, radiation protection of involved workers and the local public, and radioecological issues are key elements. Unlike most uranium mining and milling operations in Canada, the United States and Australia, WISMUT's mining and processing facilities were located in a densely populated area. As a consequence, contaminated objects like radioactive waste piles and tailings management facilities were placed close to residential areas, in some cases immediately neighbouring dwellings. The resulting exposure situation required remedial measures which are far from standard solutions. Rehabilitation of uranium mining legacies in East Germany has been going on for almost two decades now. The WISMUT Project is in an advanced state. Remediation accomplishments achieved are reflected in the positive development of radiological parameters. Due to the progress in covering waste rock piles and tailings management facilities, the advanced area cleanup as well as to the high level of treatment of contaminated seepage waters, the exposure pathways of dust inhalation, direct access to contaminated material and water usage are no longer of relevance for radiation protection. Except for a few locally elevated radon concentrations at the Schlema site, there is general compliance with radiological remediation targets established at the time when remediation started. From a radiation protection point of view, long-term remediation efforts will focus on mitigation of mine flooding related impacts and the minimisation of mid-term diffuse radiological groundwater impacts at tailings management facilities.

INTRODUCTION

From 1946 to 1990 the Soviet-German WISMUT company produced 216.000 metric tons of uranium and became with it the world's third largest uranium producer at that time. Due to the mining of low grade ore, about 800 Million tonnes of waste rock material, radioactive sludge's and overburden material were deposited at the sites. The mining and milling activities resulted in seriously affected and devastated areas of about 10.000 km² in Saxony and Thuringia, in East Germany.

In 1990 after the German re-unification the uranium production was ceased and the German government was faced with one of its largest ecological and economic challenges because WISMUT turned at once from the production to the decommissioning phase without any preparation or preplanning. Since 1991 the national corporation Wismut GmbH has been charged with decommissioning of the mines, mills and other facilities and with the rehabilitation of the sites. The government earmarked a total of € 6,4 billion (appr. US\$ 9 billion) to rehabilitate the uranium mining and milling legacy at the affected sites. The overall project includes abandonment and flooding of underground mines, relocation and covering of waste rock piles, dewatering and geo-chemical stabilisation of tailings management facilities, demolition of structures and buildings, treatment of contaminated water, site clearance and site rehabilitation.

Table I provides an overall view of the scale of the legacies left behind. Major environmental impacts due to the legacies as well as rehabilitation measures aimed at their mitigation are listed in Table II.

Table I. Uranium production legacies in Saxony and Thuringia for which Wismut GmbH is tasked with the responsibility to conduct their rehabilitation

Sites		Schlema, Pöhl	Königstein, Gittersee	Ronneburg	Seelingstädt, Crossen
Industrial areas		5,7 km ²	1,4 km ²	16,7 km ²	13,1 km ²
Waste rock piles	Number	20	3	16	9
	Area	3,7 km ²	0,4 km ²	6,0 km ²	5,3 km ²
	Volume	47 million m ³	4,5 million m ³	188 million m ³	72 million m ³
Tailings management facilities	Number	1	3	3	7
	Area	0,035 km ²	0,046 km ²	0,09 km ²	7,1 km ²
	Volume	0,3 million m ³	0,2 million m ³	0,25 million m ³	160 million m ³
Mines	Number	2	2	1	1
Open pits	Number	-	-	1	-
	Area			1,6 km ²	
	Volume			84 million m ³	

Table II. Residues, environmental impacts, and key rehabilitation measures under the WISMUT Project

Remaining objects /residues	Environmental impacts/ exposure pathways	Rehabilitation options
Underground mines	Groundwater contamination due to mine flooding	Controlled flooding including surface treatment of mine water
	Settlements, mine damages	Stabilisation of near-surface mine workings (backfilling)
Mine dumps	Radon exhalation; external radiation; incorporation of contaminants; contamination of water bodies	Mine dump relocation (underground, off-site); rehabilitation in situ involving re-grading, covering and vegetating
Worked-out open pit mine, overburden dumps	Landscape devastation, groundwater impacts	Relocation of overburden dumps into worked-out open pit mine, covering and vegetating
Tailings Management Facilities	Radon exhalation; external radiation; incorporation of contaminants; groundwater impacts	Dry in situ rehabilitation (removal of supernatant water; sludge stabilisation using deep drains; covering; treatment of supernatant, pore and seepage waters)
Contaminated structures	Use restriction	Demolition, decontamination, salvage ¹ , safe storage of contaminated materials
Contaminated plant areas	Groundwater impacts; use restriction	Area remediation (excavation/safe storage of contaminated materials, in situ soil restoration)
Rehabilitation related LLW (e.g. water treatment residues)	Radon exhalation; external radiation;	Immobilisation; storage underground, in tailings pond beach areas or engineered facilities

¹ e.g. Release of scrap metal with a total alpha surface activity of < 0,5 Bq/cm² for smelting in a steel mill

IMPLEMENTING ICRP BASIC PRINCIPLES OF RADIATION PROTECTION

Rehabilitation of areas, demolition of structures and handling of LLW under the WISMUT Project required the resolution of specific issues in terms of radioecology and translating radioprotection into practice. In essence, this applied to the implementation of basic ICRP radiation protection principles [1, 2], namely the principles of justification, limitation and optimisation. Their implementation included the successful handling of the following subtasks:

- development of assessment criteria for the justification of rehabilitation activities;
- development of a radiological monitoring system including measures to survey occupationally exposed persons;
- inventory of the initial radiological situation, assessment of baseline conditions, and object-related rationale for the justification of rehabilitation activities;
- object- and site-specific optimisation of rehabilitation measures;
- development of appropriate measuring procedures for contamination determination as well as of release measurement procedures including the establishment of a quality assurance system;
- management of radioactive wastes and residues;
- implementation of effective measures to ensure practical radiation protection for employees and to minimise impacts to the general public from rehabilitation operations;
- training and retraining of involved employees in radiation protection matters;
- public relations including the participation of persons concerned by the rehabilitation, of population groups, organisations, and public authorities, etc. (stakeholder involvement);
- management of the approval and licensing process;
- development of procedures to demonstrate the success of the restoration effort.

Justification of Rehabilitation Projects

After 1990, when the national company Wismut GmbH had become the legal successor to the former operator of the uranium production facilities, the Soviet-German stock company SDAG WISMUT, it was faced with legacies generated by insufficient compliance with radiation protection and environmental standards. As a consequence of this situation, the German Commission on Radiological Protection has categorised the legacies for which Wismut GmbH has responsibility as an intervention situation [3]. Taking rehabilitation action under such circumstances is justified on condition that the remedial actions do more good (including dose reduction) than harm [1, 2].

The "1 mSv/a" criterion has been established worldwide as a primary recommended guidance level to assess the need for rehabilitation in situations similar to those at WISMUT [3, 4]. This guidance level is geared by the variation width of the natural radiation exposure and comprises all potential exposure pathways. In the case of object rehabilitation at WISMUT, the need to rehabilitate was (and still is) derived from the results of an object and/or site specific exposure pathway analysis and by comparing the established effective dose to the guidance value of 1 mSv/a.

In 1999, the German Federal Ministry for Environment, Nature Conservation and Nuclear Safety published Calculation Bases for the Determination of Radiation Exposure due to Mining-caused Environmental Radioactivity, with a view of harmonising and providing transparency in the establishment of radiation exposure [5]. Their scope includes all age groups in line with EC Directive 96/29/EURATOM [6]. The effective dose to the reference person is calculated at the most unfavourable point or site of exposure. The following two examples illustrate typical exposure scenarios in the vicinity of mining legacies.

Example A: Radiological exposure in the vicinity of an unremediated mine dump at the Schlema site

The findings of an exposure pathway analysis established for a kid in the age group of 2 – 7 years and an adult reference person living permanently in the immediate neighbourhood of a large uncovered mine dump and using seepage water to irrigate their garden are represented in Figure 1. The analysis was based on the following mining-induced radiological data (i.e. without background radiation):

- Mean specific activity of U-238 in waste rock material = 1 Bq/g, in radioactive equilibrium with daughter nuclides;
- Rn-222 concentration on top of and alongside the mine dump: 100 Bq/m³;
- Ambient dose rate on top of and alongside the mine dump: 530 nSv/h;
- Concentration of long-lived alpha emitters on top of and alongside the dump: 1 mBq/m³;
- Seepage water concentrations: 1 mg/l U_{nat} ; 0,5 Bq/l Ra-226 and Th-230; 0,1 Bq/l Po-210 and Pb-210; 0,01 Bq/l Pa-231 and Ac-227.

Relevant exposure pathways in the case under consideration include:

- Exposure by ingestion of locally grown garden products (Food);
- External exposure by soil gamma radiation (Ext);
- Exposure by inhalation radon and its short-lived decay products (Rn/DPr);
- Exposure by inhalation of dust-borne long-lived alpha emitters (LLA);
- Exposure by direct ingestion of waste rock material (Dir-Ing).

In accordance with [5], an annual dwelling period of 7.000 hours near the mine dump and a total annual sojourn on the dump surface of 250 hours (child) and 100 hours (adult), respectively, were assumed.

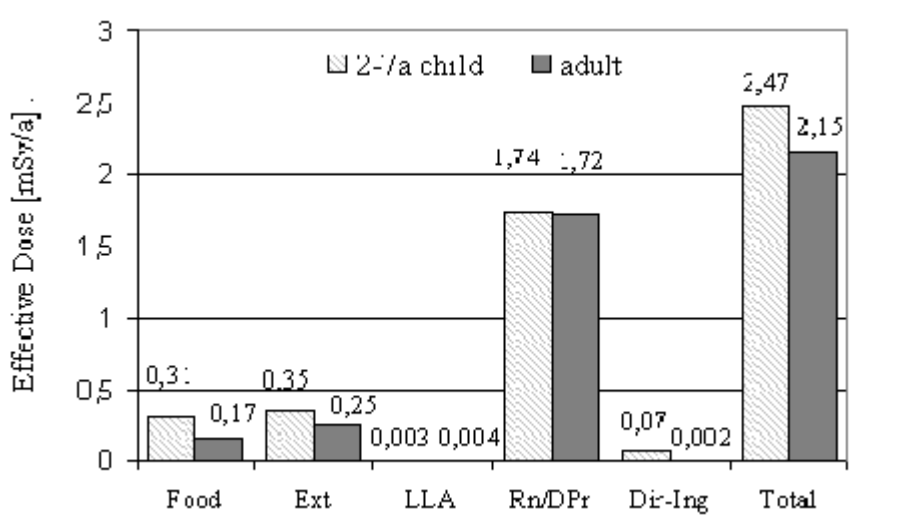


Fig. 1. Typical exposure situation at unremediated uranium mine dumps

Example A illustrates the predominance of the exposure pathway "Inhalation of radon and its short-lived decay products". Such predominance is found in mine dump surroundings in most instances as long as the water pathway, and in particular the use of contaminated water for drinking or for preparing baby food, does not become relevant (cf. Example B).

Example B: Exposure by the use of water from watercourses contaminated by seepage leaking from an unremediated tailings management facility

This example considers the use of a watercourse for the irrigation of field and garden crops, livestock watering (each contributing 25 % locally produced food to annual consumption rate) and for drinking (100 %), plus fish consumption. The nuclide vector, which has to be determined completely, has a dominating influence on the calculation result. The vector considered in this case was identified at a small creek running between two large tailings management facilities at WISMUT. Typically the nuclide vector of surface water at such sites is dominated by uranium nuclides (see Table III).

Table III. Nuclide vector for a watercourse in the surroundings of a not yet remediated tailings management facility (C_i – activity concentration of nuclide i in the water)

Nuclide	U-238	U-234	Th-230	Ra-226	Pb-210	Po-210	U-235	Pa-231	Ac-227
C_i [Bq/l]	5,2	6,1	0,17	0,02	0,025	0,025	0,24	0,015	0,015

Figure 2 shows the results of the exposure pathway analysis for the age group [$< 1a$] and for adults. They detail dose contributions by the exposure pathways drinking water (DW), fish consumption (Fi), mothers' milk/baby food consumption (MM_BF), consumption of field and garden crops other than cereal products (FGP) and the consumption of dairy and meat products (DMP). Such a scenario typically identifies an effective dose in excess of 1 mSv/a solely for the baby, wherein radiation exposure levels are dominated by the use of water for drinking purposes and the preparation of baby food.

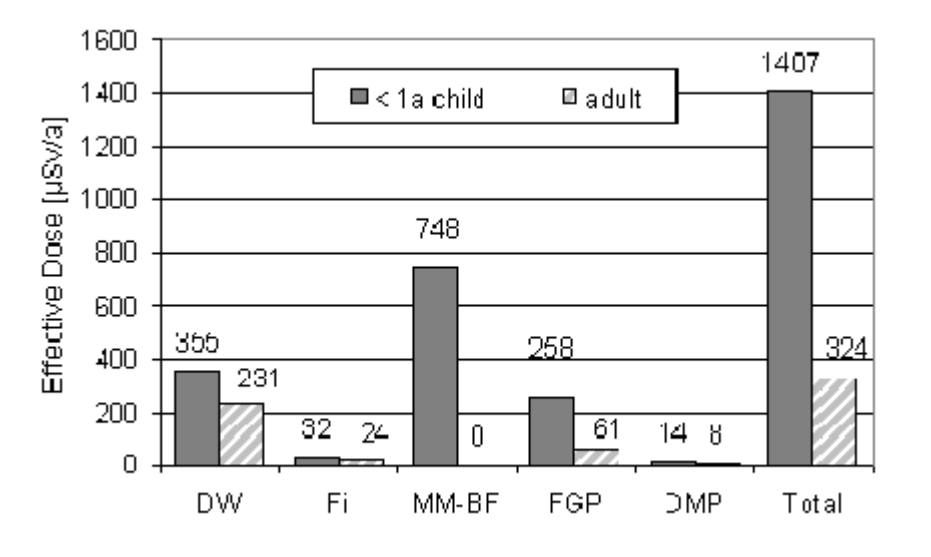


Fig. 2. Typical exposure pattern via the water pathway at an unremediated tailings management facility

Limitation of radiation exposure to workers and the general public

In analogy to justification, limitation of exposure to workers and the general public in intervention situations in fact requires again the use of recommended guidance levels instead of limiting levels. However, as remediation-induced exposures to remediation workers are typically small and may be kept below 6 mSv/a (dose limit for occupationally exposed persons Category B [7]) or even below 20 mSv/a (Cate-

gory A) within reasonable spending limits, dose levels to workers are measured by the limiting level in accordance with the applicable Radiation Protection Ordinance [7]. Annual exposures to workers dealing at WISMUT with remediation above ground currently range from 1 to 4 mSv/a, with the more elevated rates applying to workers employed in tailings remediation. Above ground workers are classified as occupationally exposed persons Category B. In order to ensure radiation protection for workers dealing with remediation in the mines (underground workers), WISMUT runs a comprehensive mine ventilation system. As a result, effective doses to them range from 1 to 6 mSv per year, but may peak at 10 mSv/a in exceptional cases (predominance of the exposure pathways inhalation of radon progeny as well as of dust-borne long-lived alpha emitters). Therefore, underground workers are classified as occupationally exposed persons Category A.

Legal grounds require that the assessment of rehabilitation-induced radiological exposure to the general public is established by the limiting value of the Radiological Protection Ordinance of the former GDR [8] which is still applicable to the WISMUT rehabilitation project, i.e. 5 mSv per year and averaged over a period of 50 years not more than 1 mSv per year. In practice, however, the criterion of 1 mSv/a in accordance with the recommendation of the German Commission on Radiation Protection is typically being used as evaluation basis [3]. As remediation-induced effective doses to the general public are virtually significantly smaller than 1 mSv/a, both approaches yield similar conclusions. Solely dust deposition on land located in the immediate neighbourhood of ongoing remedial operations and being used for horticultural purposes might cause doses in excess of 1 mSv per year. However, as operations near vicinity properties are typically of limited duration and accompanied by comprehensive dust suppression measures, remediation-induced non-compliance with the criterion of 1 mSv/a via this exposure pathway is a rare exception.

Optimisation of rehabilitation measures

Optimisation of rehabilitation measures for mining legacies is definitely among the most demanding challenges. The reasons are as follows:

- Dose reduction occurs within the variation width of the natural background radiation. This background is "omnipresent" and can be determined with limited accuracy only. As a consequence, it is hard to determine the net benefit of a remedial measure in terms of dose minimization.
- Rehabilitation costs often increase supra-linearly with gains in net benefits, that is to say that further dose reductions would involve increasingly cost-intensive measures.
- Besides environmental aspects (not limited to radiological environmental impacts), optimisation also has to take social and economic aspects as well as issues of sustainability into consideration. In particular the interests of persons concerned, such as residents, local and state authorities, regulatory bodies, etc. (known as stakeholder involvement).

Reviewing fundamental decisions on WISMUT rehabilitation matters, the consultant to the Federal Ministry for Environment, Nature Conservation and Nuclear Safety used an approach to the cost-benefit analysis which was primarily based on the determination of the collective dose and on the number of health damage events deduced from risk factors (e.g. cancer incidences, loss in life expectancy). The amount of health damages was monetarised by comparison with the amount of cost which the society would be prepared to pay in order to attain a certain degree of damage reduction (described by the so-called "alpha value"). The optimum rehabilitation option was the one that brought the sum of remediation costs and damage-equivalent costs down to a minimum [9].

A cost-benefit analysis conducted in such a way is not undisputed, primarily because of the uncertainties of intermediate results (problem: calculation of realistic collective doses) and of assumptions to be made (alpha value identification; integration time for the post-remedial condition [200 or 1000 years?]; application of dose cut-off criteria, etc.). The procedure used by the regulatory consultant has proved its worth as a useful sensitivity analysis tool in deriving fundamental decisions for large and complex rehabilitation objects. In an extended approach, also non-radiological risks were included in the cost-benefit analysis. As a result, cost-relevant parameters were more easily identified and decision-making became more transparent. Instead of the pure cost-benefit analysis, WISMUT successfully applied a multi-attribute analysis which in addition to costs also considers what are known as soft factors, such as social factors, aspects of licensing and planning regulations, or acceptance issues: in short, involvement of all stakeholders.

RADON: A SPECIAL CASE?

During the early years of the rehabilitation project, there were different approaches to separately evaluate elevated environmental radon concentrations. Their existence was motivated by the "ubiquity" of radon and the temporal and local variations in natural radon background concentrations (see, e.g., [10]). For the purpose of radiation protection of workers and the public, however, the exposure to radon should be considered on a par with all other pathways of exposure. This means for the population, in particular, to integrate doses due to the inhalation of radon and its progeny into the sum of the partial contributions to the effective dose which is to be compared to the criterion of 1 mSv/a. This approach, consistently followed by WISMUT, is reflected in the Calculation Bases for the Determination of Radiation Exposure due to Mining-caused Environmental Radioactivity of 1999 [5].

Site features such as the proximity to residential areas of WISMUT legacies left behind on the surface (mainly mine dumps) require differentiated reclamation solutions which also have to consider local dispersion conditions for radon and progeny. Therefore, neither German legal rules and standards [7, 8] nor the recommendations of the German Commission on Radiological Protection [3] prescribe any maximum admissible rates for radon exhalation from mine dumps or tailings bodies (see, in contrast hereto, the EPA Standard of 20 pCi/(m²s) [11], equivalent to ca. 0,7 Bq/(m²s)). The need for a flexible application of maximum admissible exhalation of radon from reclaimed mine dumps is particularly apparent at the Schlema site where 42 million m³ of waste rock material were deposited in 23 dumps, some of them located adjacent to residential estates. Radon exhalation from these steeply sloped mine dumps is dominated by convective internal airflow through the dump (due to a thermal gradient and barometric pumping) and accompanied by significant temporal and local variations. These variations plus nocturnal drainage flows provide a rather heterogeneous picture of local radon concentrations [12]. The reclamation target consists in achieving an outdoor mine-related radon concentration at exposure-relevant sites of < 50 Bq/m³. Having regard to standard scenarios in accordance with [5] and when applying the dose conversion convention recommended by ICRP 65 [13], this concentration level equals an effective dose of less than 1 mSv per year. On the assumption of a natural background concentration of 30 Bq/m³, annual average radon concentrations of < 80 Bq/m³ will have to be achieved. This reclamation target represented (and continues to pose) a genuine challenge to WISMUT's radiation protection department and cannot be achieved by a cover with maximum admissible exhalation rates (e.g. 0,7 Bq/(m²s)). Placement of a 1 m thick cover of soil material exhibiting low permeability to gas of < 10⁻¹² m² allows to control convective flows in steeply sloped mine dumps [14].

Mitigation of mine-related radon at the Schlema sites poses another challenge. As flooding of the Schlema mine reaches its final stage, the flood water will not rise to a level to fill all near-surface mine workings. For the time being, the mine workings continue to be fairly extensively ventilated thus creating a permanent negative pressure of the mine air versus outdoor barometric pressure. Experiments run by the

Environmental Monitoring and Radiation Protection Department of Wismut GmbH have demonstrated that shutting-off ventilation would result in a rapid increase in radon concentrations in dwellings. Basement concentrations in the order of up to 100.000 Bq/m³ were recorded. Tracer gas investigations have demonstrated that these concentration levels are due to convective air currents from the mine. Since extensive mine ventilation using a central exhaust shaft does not represent a sustainable rehabilitation solution, the search continues to identify local technical resolutions allowing to resolve the mine-related radon issue with due regard to technical and economic factors in the long run.

ENVIRONMENTAL IMPACT DEVELOPMENT AND RADIATION EXPOSURE TRENDS AS A RESULT OF REMEDIATION PROGRESS

Rehabilitation of uranium mining legacies in East Germany has been going on for almost two decades now. Mine flooding is well advanced though it must not be overlooked that the final flooding stages pose the greatest challenge in terms of technical effort and of minimising radiological, conventional toxic and geotechnical environmental impacts. All sizeable waste rock piles were either covered (Schlema site) or relocated into the worked-out Lichtenberg open pit mine (Ronneburg site). Rehabilitation of the large tailings management facilities (Seelingstädt and Crossen sites) is 50 % complete. Physical work at these sites will have to continue till ca. 2018, making tailings pond rehabilitation the longest running single remedial measure. Nearly 80 % of the initially budgeted € 6.4 billion have been spent, from today's point of view the remaining ca. € 1 billion will suffice to cover both completion of remedial measures and long-term tasks.

Remediation accomplishments achieved are reflected in the positive development of radiological parameters. In March 2009, WISMUT has drawn up an interim balance on the achievement of radiological protection targets at the various sites under remediation. This stocktaking came to the following conclusions:

- Due to the progress in covering waste rock piles and tailings management facilities, in area cleanup as well as in catchment and treatment of contaminated seepage waters, the exposure pathways of dust inhalation, direct access to contaminated material and water usage are no longer of relevance for radiation protection.
- Except for a few locally elevated radon concentrations at the Schlema site, there is general compliance with the guidance value of 1mSv/a.

From a radiation protection point of view, long-term remediation efforts should focus on:

- Mitigation of mine flooding related impacts on the radon situation in dwellings (impacts from near-surface, non-flooded mine workings); anticipated solution: design of local ventilation solutions; and
- Minimisation of mid-term diffuse radiological environmental impacts via groundwater; solutions: completing covering of all tailings management facilities, completing controlled mine flooding, contamination removal from highly stressed and severely loaded industrial areas.

The positive development embarked on is best demonstrated by the following three examples. As a first example, Figure 3 illustrates the trends in controlled water-borne discharge of uranium and Ra-226 as the principal radiological components in the water. Effluents are mainly mine waters from the Ronneburg, Schlema, Gittersee and Königstein mine sites (flooding of mines with concurrent treatment of flood water). The significant decrease in concentrations in discharged waters reflects a stronger drop in contaminant and activity releases, respectively, in comparison to decreasing water discharge volumes. These results were achieved since high-performance water treatment plants went on line at all WISMUT sites.

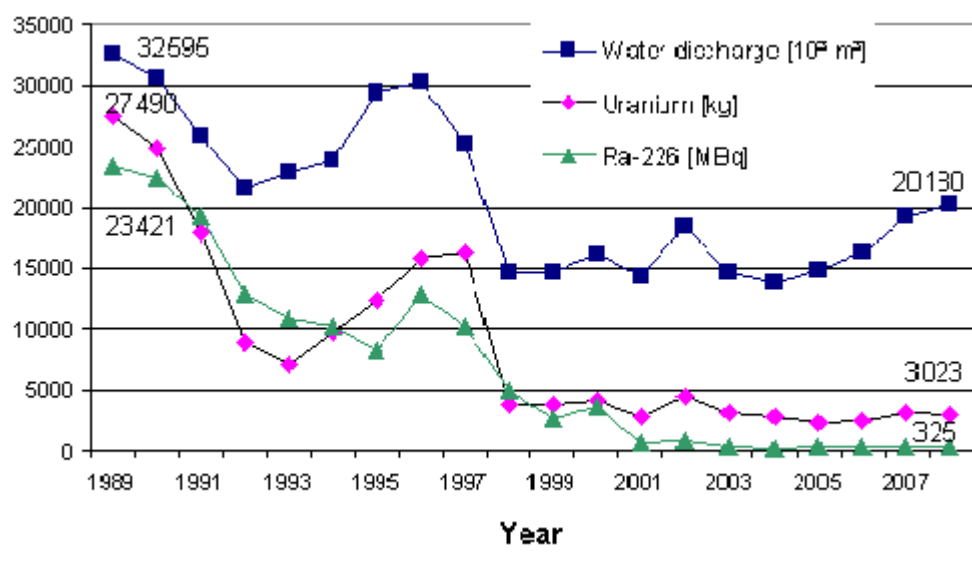


Fig. 3. Evolution of controlled discharges with water (sum of discharges from all WISMUT sites)

As a second example, Figure 4 illustrates the impact which regrading and covering of waste rock pile no. 66/207 at the Schlema site had on radon concentration at the toe of the dump. Regrading of the waste rock pile resulted in flattening the slopes and an improved circulation of air in the area around the dump where residential areas are located. Thus, an initial improvement of the local radon situation was achieved (cf. comparison of summer data 2002 versus 2001). But it was not before the dump slopes were covered with a 1 m thick layer of inert material exhibiting adequate radon proofing properties that the convective fluxes within the waste rock pile were eliminated in summer 2003. Since then, radon exhalation rates have been kept permanently at a low level and ensuing radon concentrations remain low. Regular measurements have exhibited long-term radon concentrations of below 80 Bq/m³ resulting in mine-related effective doses to residents close to the dump toe of less than 1 mSv/a.

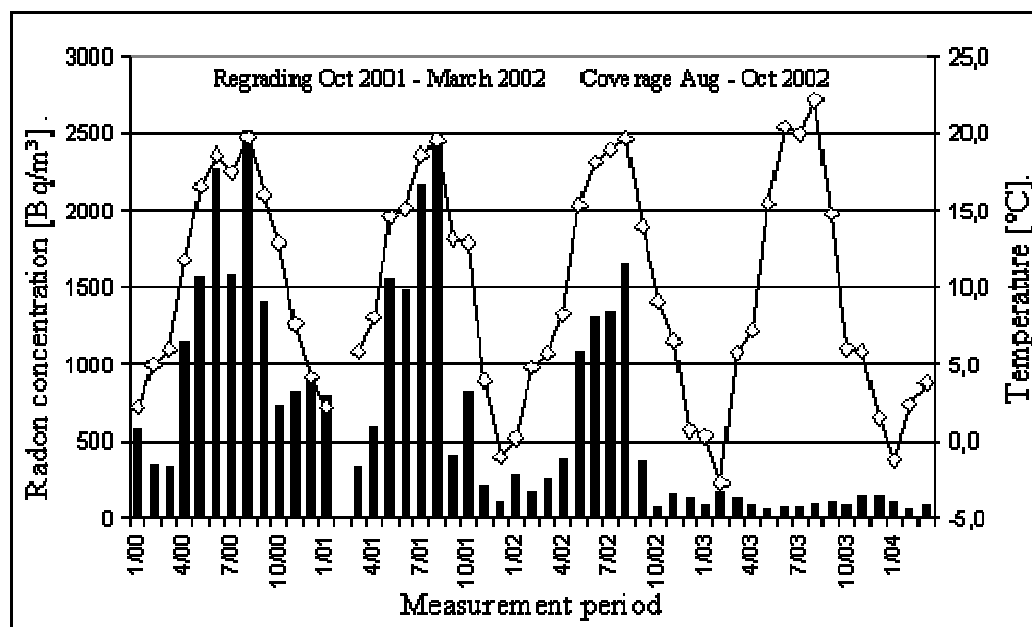


Fig. 4. Evolution of pre- and post-rehabilitation radon concentrations at mine dump 66/207

As the third example, Table IV reflects the changes in the nuclide vector towards lower radioactivity for the watercourse in the surroundings of the tailings management facility as a result of remediation progress (see Example B – typical exposure situations, cf. Table III)

Table IV. Pre- and post rehabilitation nuclide vector for a watercourse in the surroundings of a tailings management facility (C_i – activity concentration of nuclide i in the water)

Nuclide	U-238	U-234	Th-230	Ra-226	Pb-210	Po-210	U-235	Pa-231	Ac-227
C_i [Bq/l] - pre	5,2	6,1	0,17	0,02	0,025	0,025	0,24	0,015	0,015
C_i [Bq/l] - post	0,83	0,85	0,001	0,02	0,002	0,006	0,04	0,008	0,001

POSITIONING OF RADIATION PROTECTION ISSUES WITHIN THE WISMUT REMEDIATION PROJECT, LONG-TERM TASKS

Just as happened elsewhere, the WISMUT Project, launched to rehabilitate enormous radioactive legacies, had (and still has) to acknowledge that the "public perception of radioactivity" is not free of emotions and connected with the difficulty to illustrate matter-of-factly the risks resulting from radioactivity. In this respect, radioecological issues and specific radiation protection issues influenced remediation design well beyond practical science applications – and typically were given priority in public debate. But the remediation license and permit statistics run by WISMUT reveal otherwise: radioecology and radiation protection are only a segment of the factors to be considered in decision-making on rehabilitation measures. For example, out of a total 7.863 remediation licenses and permits granted by September 30, 2009, only 1.124 were permits issued under radiation protection regulations, the others were granted under the Mining Act, the Water Law, the Building Code, and the forestry legislation. In addition to legal aspects and aspects relevant to the environment, socio-economic issues had also to be considered such as the future development of the affected regions, job situation and job creation, as well as the creation of attractive living conditions for rising generations. International organisations like IAEA also consider these factors in their assessment of large-scale environmental projects (see, e.g. [15]).

Legislation and standards provide a frame of reference to abide by. Recommendations need expert translation into practice. This translational effort must not follow stereotypes. This means in particular that guidance values for justification of remedial measures cannot be unilaterally interpreted as remediation goals. With due regard to site-specific features and insight into complex situations, recommendations and the guidance levels they contain have to be applied in a proper way to decision-making on the justification and optimisation of rehabilitation measures. Practice has proven that such approach contributes to transparency of decision-making and typically enhances the efficiency of the permitting process.

In retrospect on almost 20 years of implementing the WISMUT project, some conclusions may be derived on the radiological aspects of remediating the legacies of uranium mining in East Germany; one of these features is that radioecology and radiation protection found a ready field for constructive application whenever it was possible to:

- prefer measurements, if implementable within reasonable spending limits, to modelling;
- optimise and update environmental impact monitoring and submit it to Quality Assurance;
- make the decision-making process transparent and ensure stakeholder involvement by expert public relations; and
- document adequately remediation decisions, remedial success and the assessment of residual contamination.

Following the completion of the remedial work proper, long-term tasks will remain to be accomplished, such as:

- treatment of radioactively and chemically contaminated waters;
- maintenance and, if required, repair of cover systems, hydraulic structures, roads and trails as well as of remaining mine workings; and
- long-term monitoring of residual environmental impacts.

WISMUT acts on the assumption that it will take up to 30 years to complete the long-term tasks. This period will be preceded by the post-remedial phase during which evidence of the remedial success has to be substantiated. During both phases, water treatment will definitely be the single most cost-intensive measure. But long-term monitoring will also keep WISMUT busy for a couple of years to come. From a radiological point of view, stable long-term mitigation of mine-related radon at the Schlema site remains the number one challenge.

In the end, the success of a remedial action will be measured by the degree in which radiological and conventional hazards will be reduced to a sustainable and acceptable low level. Thereby, the policy "Returning WISMUT legacies to productive reuse" is pursued. That is to say that the reclaimed areas are to be returned preferably to high-grade reuse so that they may be used and become available for integration into local and regional development plans. In WISMUT's understanding, conducting reclamation along these lines is the best way to implement the principle of sustainability. Reclamation conducted in the Schlema community, once severely affected by uranium mining activities, is a case in point. Thanks to successful reclamation, Schlema recovered its status of a health spa in 2006, a status which it used to have before uranium mining started at the site. The venturesome idea, venturesome not only from a radiological point of view, to erect a golf course on the surface of a reclaimed mine dump having a radioactive inventory that is anything but insignificant became reality last year at Schlema. What became known as the "New Ronneburg Landscape" may be quoted as another case in point: this new landscape centred around the fill body covering the former open pit mine was the core area of the 2007 German national horticultural exhibition which attracted more than 1,4 million visitors who could see for themselves how the former uranium mining region had emerged as a landscape full of attractive prospects for its people.

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