Sustainability Assessment of the Results of the WISMUT Environmental Remediation Programme (1990-2011)

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Abstract

Since 1991 the federally owned Wismut GmbH is properly performing the closure and environmental remediation of the legacy of the former Soviet-East German uranium mining industry. Twenty years of remediation have fundamentally changed the face of the former uranium mining provinces in Saxony and Thuringia. A foundation was laid to overcome the former monostructures related to uranium mining. Since remediation of surface liabilities such as the waste rock piles and tailings management facilities is far advanced and modern water treatment plants are being operated, radioactive and non-radioactive emissions into water, air and soil are sustainably mitigated. By December 31, 2010 from the total of 3,700 ha of former mine land 1,072 ha have been sold or leased after successful remediation, mainly for industrial use, agriculture, forestry or recreational purposes. In order to ensure the sustainability of the rehabilitation, future activities must focus on water treatment, maintenance and care of barrier systems and technical installations, environmental monitoring, and data/information management to enable institutional control of sites and properties which have been remediated for restricted use only. The long-term goal is to achieve self-regulating, close-to-nature systems to sustainably minimize emissions post-closure.

Introduction

Following German unification in 1990, uranium production by the then Soviet-(East) German stock company (SDAG) Wismut was terminated, and in the following year, the successor company, Wismut GmbH was mandated by federal legislation to perform decommissioning and rehabilitation of the mining legacies. More than 40 years of uranium mining and milling in Saxony and Thuringia had left behind wastes of "singular dimensions", which prompted the German federal government to earmark financial resources to the tune of up to DM13 bn. (€6.6 bn.) out of the federal budget of the recently reunited Germany to fund the rehabilitation of the environmental legacy. Dependable or detailed planning covering the period "after uranium mining" was inexistent, nor had the legacies of gigantic dimensions in any way been minimised at an early stage during the production phase by targeted and foresighted action of the mining company. Plans for a possible continued operation of individual mining sites were doomed both for economic and political considerations.

The environmental damage caused by SDAG Wismut confronted the newly established remediation company in 1991 with an intervention situation in terms of radiological protection of a very particular kind requiring the phasing out of production, stock taking, mitigation of immediate hazards, and development of technical remediation concepts. This had to be done in parallel to corporate restructuring and opening up of the formerly sealed off large-scale company which still comprised five

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mining and two processing sites, and without losing sight of the social consequences for the remaining 45,000-strong workforce (Fig. 1).

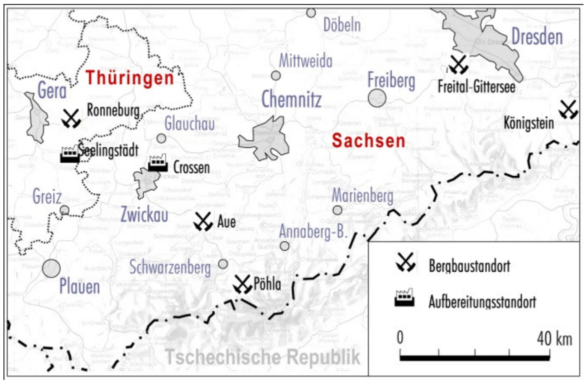

Figure 1
Location of sites under remediation of Wismut GmbH

This contribution is intended to outline how the damage caused by Wismut uranium mining to the environment prior to 1990 has been mitigated and to show the novel, but nevertheless sustainably balanced state of the environment which has been reached. Emphasis will be on the extent to which the essential economic and environmental objectives of the remediation have been fulfilled and to what degree they have been implemented in a sustainable manner. With detailed consideration of legal framework conditions, of technical aspects and of individual remedial steps being omitted here, for more information on these topics please refer to the large number of detailed publications and recent presentations found in the references (a.o. Wismut 2011; Mann & Paul 2010; Paul 2010; Barnekow et al. 2010).

Achievements of the remediation operations

The remediation of more than 1,000 individual objects have been addressed by the Wismut Restoration Programme with the following key activities:

(a) Decommissioning and closeout of five underground mines including more than 100 shafts and surface openings, with mine voids totalling a volume ca. 80 million m^3, plus flooding of the mine workings;
(b) Dismantling of facilities, demolition of buildings, and surface area rehabilitation on the major portion of property totalling ca. 3,700 ha assigned;
(c) Stabilisation/remediation or relocation of ca. 50 waste rock piles with a total volume of ca. 325 million m^3 of contaminated waste rock and low-grade ore;
(d) Stabilisation/remediation of seven tailings management areas with a total volume of more than 160 million m^3 of processing residues and contaminated sludges;
(e) Backfilling of the mined-out Lichtenberg open pit mine at the Ronneburg site with a residual volume of ca. 84 million m^3;
(f) Construction and operation of facilities to collect and treat contaminated mine, supernatant and seepage water, including the immobilisation and safe disposal of treatment residues;
(g) Environmental monitoring.

By December 2010, remediation operations were almost completed. The status of key remediation tasks is listed in Table 1. At the end of 2010, spending totalled of ca. 5.4 bn. € (see Table 2).

Table 1 Remediation progress achieved (as of 31.12.2010)

	Sites in Thuringia *		Sites in Saxony **		Wismut Total	
	Achieved	Complete	Achieved	Complete	Achieved	Complete
Mine workings abandoned	2,040 km	100 %	777 km	98 %	2,817 km	99 %
Backfilling of mine voids	5,766 Tm³	100 %	752 Tm³	93 %	6,518 Tm³	99 %
Mine workings flooded	19.4 Mm³	99,7 %	41.9 Mm³	86 %	61.3 Mm³	90 %
Mine workings stabilised	37.8 km	100 %	187.0 km	93 %	224.8 km	94 %
Demolition of facilities	512.4 Tm³	96 %	264.9 Tm³	81 %	777.3 Tm³	90 %
Contouring ***	298.3 Mm³	92 %	32.4 Mm³	94 %	330.7 Mm³	92 %
Final Capping	14.7 Mm³	70 %	9.3 Mm³	77 %	23.9 Mm³	72 %
Reclaimed areas	1,336 ha	67 %	563 ha	68 %	1,899 ha	68 %
Water treatment	116.8 Mm³	66 %	235.6 Mm³	52 %	352.4 Mm³	56 %

* Ronneburg und Seelingstädt sites, ** Schlema-Alberoda, Pöhla, Königstein, Dresden-Gittersee, and Crossen sites, *** Sum of excavation/placement including mine dump relocation

Table. 2 Allocation of funds for selected object classes, according to sites, in million € (as of 31.12.2010)

	Ronneburg, Seelingstädt, Crossen	Aue, Pöhla	Königstein, Gittersee
Underground remediation	412.7	337.7	450.3
Sealing of shafts and surface openings	155.2	43.0	11.5
Waste rock pile remediation	546.7	194.2	39.5
Backfilling of open pit mine	135.4	-	-
Demolition	137.1	30.3	16.5
Area reclamation	266.9	21.1	12.6
Tailings pond remediation	445.3	5.9	-
Subsidence damage	22.4	12.2	1.9
Uranium disposal	74.4	4.6	94.1
Contaminant disposal	80.1	6.7	1.1
Exposure pathway analysis and monitoring	191.2	48.7	58.3
Water treatment	285.8	112.6	198.8

Sustainability in the context of mine remediation

In 1987, the UN-appointed World Commission on Environment and Development has defined sustainable development as one which implies meeting the needs of the present without compromising the ability of future generations to meet their own needs (UN 1987). In line with this, sustainability is made up of three intertwined aspects: environment (ecological aspects), economy (economic aspects) and society (social aspects). In this generalised form, the concept of sustainable development may in fact be precisely applied to the mining industry. The potentially negative impacts had already been described by Agricola in his “Twelve Books on Mining“ in 1556. According to the concept, all aspects of a future operation, including closeout and remediation, have to be considered during the design phase for a new mining project (*life-cycle-approach*). Potentially negative impacts of planned activities have either to be avoided or their consequences be limited in a manner to ensure that hazards be avoided and resources are conserved and their usability not be adversely affected by contamination. This is particularly true for uranium mining because of the radioecological risks involved and the risk of dispersing long-lived radionuclides into the hydrosphere and ecosphere (WNA 2008; SSK 2008; IAEA 2009), as well as in the context of the ongoing debate on the net energy balance of uranium mining and processing (Mudd & Diesendorf 2007; Prasser et al. 2008).

Much more complicated, however, is the application of the sustainability concept in intervention situations. That is in matters of environmental protection after the environmental damage has happened due to past unsustainable action where mitigation is required. The remediation of the former production sites of WISMUT is an example. The notion of sustainability requires interpretation and redefinition since no established standards are available. Sustainability in the context of mine remediation in intervention situations will follow a number of principles as considered in the Wismut Environmental Restoration Programme:

1. With due regard to reasonable spending policies, the existing impairments are to be reduced to socially accepted and reasonable levels. To this end, remedial options are to be carefully and comprehensively analysed with regard to their ecological, economic and social aspects and also for long-term stability and follow-up costs. Financial resources provided by the federal budget have to be spent in an economically reasonable manner.
2. Remediated former mining properties are to be reclaimed for high-end reuse with the aim of promoting long-term regional and community development as well as job creation schemes.
3. Remedial action should result in a self-sustaining system that requires no long-term active measures and has minimal residual risks.
4. Achievements of remedial action have to be comprehensively documented and made accessible to the general public. Relevant documents, information, and data have to be safely stored for long-term access, and to meet the needs of institutional control.

Derivation of basic remediation strategies involving numerous individual projects at a variety of locations required an integrated planning approach. Difficulties in the early 1990s were that an inventory of issues and data acquisition had to be performed and decision-taking prepared while most urgent measures to terminate production and mitigate immediate hazards had to be speedily initiated. A combination of ”bottom-up‘ and “top-down approach” was chosen as a methodological planning approach ensuring the continuity of remedial projects while preserving the conceptual consistency of all individual measures.

Among the key issues to be addressed in deriving basic decision options for the remediation of large-scale objects, such as the Lichtenberg open pit at the Ronneburg site or the large tailings management areas, was the search for long-term stable remedial solutions to be characterised by robustness, minimal residual risks, and low post-remedial care. To this end, cost-benefit and multi-attribute analyses were performed on the basis of conceptual site models by means of which remedial efforts were balanced and remedial measures adjusted to site-specific requirements. The remedial concepts and technologies applied were designed by integrating international state-of-the-art know-how and expertise. With due regard to ecological and economic boundary conditions, the overall objective of remediation remains the controlled and safe rehabilitation of all objects having potential sources of contamination to affect human health and the environment. Minimisation of potential hazards related to individual WISMUT objects was either completed by removing contaminant sources involving excavation and off-site disposal or by reducing release rates involving capping or active and passive treatment measures as in the case of discharged mine water. The selection of remedial measures was guided by the search for site-specific or object-specific solutions to ensure an optimum relationship between remedial costs and attainable environmental benefits. With this in mind, the basic decision to remediate all tailings management areas of WISMUT *in situ* was taken including the removal of supernatant water and partial dewatering of solid materials. This remedial strategy which is both expensive and geotechnically challenging given the size of the fine-grained sludge zones was approved as the optimum remedial solution for the respective site conditions on the basis of a probabilistic risk assessment following an extensive regulatory review process. Relocation of the major portion of waste rock from the Ronneburg site into the mined-out Lichtenberg open pit was the result of the search for an optimum inter-site solution.

Sustainability of the WISMUT Remediation Project

Reduction of negative environmental impacts

Mitigation of hazards

The most sustainable method to reduce negative environmental impacts is the removal of the sources. Examples of this approach include permanently sealing of shafts and surface openings as well as the stabilisation of near-surface mine voids. This was accomplished at a cost of ca. 210 million € spent by 2010. Likewise, the backfilling of the Lichtenberg open pit at the Ronneburg site was completed using nearby waste rock piles. This additionally allowed to resulted in resolve the issue of unstable pit walls (Figure. 2).

In the same way, efforts are undertaken to decontaminate contaminated areas and reclaim them for unrestricted reuse. As cost-benefit considerations are an impediment to this approach, large hazards like waste rock piles and tailings management areas are stabilised for the long term by regrading and capping.

Figure 2 Post-mining landscape at the Ronneburg site in 2010: backfilled former Lichtenberg open pit surrounded by waste rock pile footprint areas. © Wismut GmbH

Limitation of emissions

According to radiation protection legislation, Wismut GmbH is obliged to monitor emissions and exposure with regard to radioactivity at the sites under remediation and submit annual reports to the agency. The measurement programmes cover the propagation pathways of air, ground and surface water as well as soil. The measuring network for the sole basic programme to monitor environmental radioactivity consists presently of more than 600 locations. Analysis and interpretation of the respective annual measurement results allow conclusions concerning the reduction of pre-existing impacts as a result of remedial action.

Key parameters of the **atmospheric pathway** monitoring programme include the components of Rn-222 in near-ground air, dust and long-lived alpha emitters in suspended dust as well as Ra-226 in precipitated dust. Figure 3 provides an overview of radon emissions from exhaust shafts of the five underground mines from 1989 to 2010 which in addition to the radon release from waste rock piles are a primary source of radon emissions at the sites. It demonstrates the significant reduction down to < 5 % of 1989 levels (total of all sites), a significance equally reflected in exposure measurements.

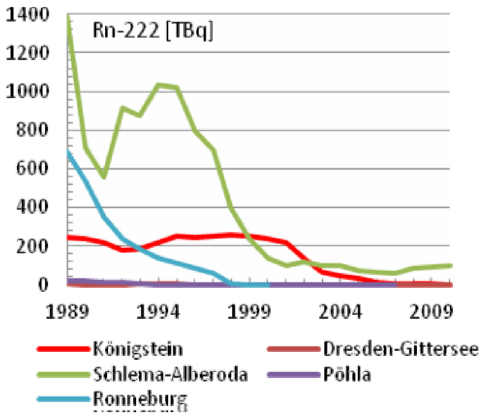

Figure 3 Evolution of radon discharge from exhaust shafts of the Königstein, Dresden-Gittersee, Schlema-Alberoda, Pöhla and Ronneburg underground mines(1989-2010)

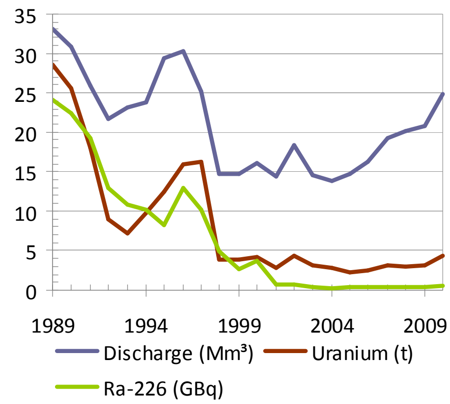

Figure 4 Evolution of effluent discharges and related emissions of uranium and radium-226 during the period of 1989-2010, total of all sites under remediation

When production was terminated, **ground and surface water bodies** in the catchment areas of the Elbe, Zwickauer Mulde and Weiße Elster rivers were considerably affected by effluents and uncollected seepage. As an example, in 1989 the total uranium load discharged from all sites amounted to 27.5 tons. Between 1979 and 1989, the quantity of annual uranium discharges from the Schlema-Alberoda, Crossen and Pöhla sites into the catchment area of Zwickauer Mulde river alone varied between 9.5 and 22 tons (Michel et al. 2010). As a result of gradual phasing out of mine water pumping when mine flooding was initiated, collection of contaminated seepage and the simultaneous construction and operation of eight state-of-the-art water treatment plants at the sites under remediation, water-borne emissions diminished significantly. Since 1998, the quantity of uranium emitted at all sites, for example, varies between 2.2 and 4.5 tons and hence is down to only 10 – 20 % of pre-remediation levels. For emissions of Ra-226, an even more dramatic reduction to a mere 1-2 % of initial levels was attained. Figure 4 depicts the evolution of discharged uranium and radium loads (emissions) for the 1990-2010 period. A similar picture emerges when considering the exposure situation in the receiving streams Weiße Elster and Zwickauer Mulde which reflects the summarised impact from sites in Thuringia and western Saxony (Figure 5). Similar results are expected for a host of smaller mine-impacted receiving streams or other key quality parameters such as nickel or arsenic.

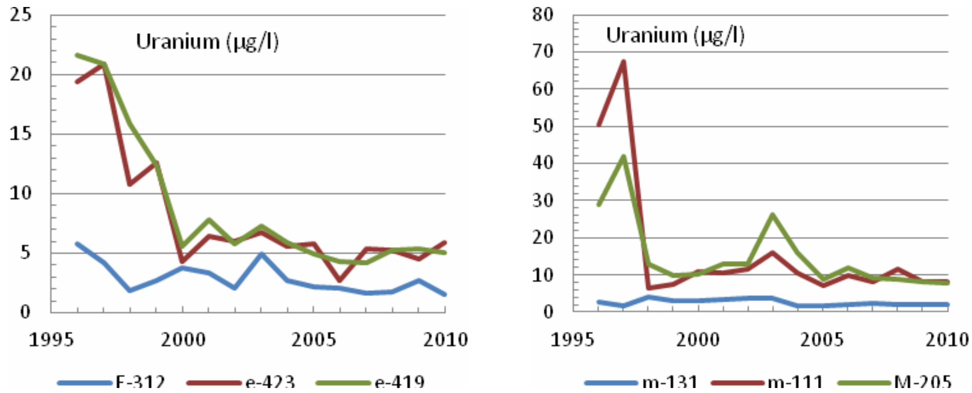

Figure. 5 Evolution of uranium concentration levels at selected measuring points along the Weiße Elster (left) and Zwickauer Mulde (right) rivers due to direct discharge and diffuse water flow at the Seelingstädt and Ronneburg sites (W. Elster) and. Schlema-Alberoda and Crossen (Zw. Mulde)

With regard to the reduction of mining-originated additional individual doses to the general public it can be ascertained that as a result of progress achieved in capping of the waste rock piles and tailings ponds and surface area remediation as well as due to the collection and treatment of contaminated seepage, the exposure pathways of dust inhalation, direct access to contaminated materials as well as use of water bodies are no longer of relevance in terms of radiological protection. According to an interim balance established in March 2009 covering the sites under remediation located in Saxony, the reference level of 1 mSv/a is no longer exceeded, except for a limited number of locations in the immediate vicinity of large waste rock piles at the Schlema site where radon emissions remain elevated. For the sites located in Thuringia a similar detailed evaluation remains to be done, but basically it may be assumed that remediation goals with regard to radiation protection have been met there as well.

Rehabilitation for high-end reuse to promote investments

It is standard practice to remediate contaminated areas whenever possible for unrestricted reuse; however, the sheer size of some large objects and cost-benefit considerations do not always justify such policy. Therefore, remediation in many cases needs to be targeted to a specific type of reuse. Reclaimed areas are aligned with economic considerations, mainly to communities, but also to individuals.

The land area assigned to Wismut GmbH 1991 amounted to a total of ca. 3,700 ha. In 1992 WISMUT still owned ca. 3,400 ha. As of December 2010, 709 ha of the reclaimed areas had been sold: 249 ha for agricultural and forestry use, 255 ha for public projects or to individuals, 125 ha for commercial/industrial or mixed use, 64 ha for the Schlema golf course, and 16 ha for a housing development. In addition, some 363 ha are currently leased, mainly for agricultural use, but also for recreational and leisure time purposes. In coordinating with local governments suitable boundary conditions were put in place which contributed largely to revitalise former WISMUT sites and attract investors. Examples include, to establish a solar farm at the site of the former Schmirchau mine woodlands and greens spaces to promote tourist and recreational infrastructure. Outstanding examples include the rehabilitation of waste rock piles in the centre of the town of Schlema, a prerequisite for the establishment of the spa park, as well as the creation of a golf course on top of the reclaimed waste rock piles. In Ronneburg following the reclamation of a former waste rock pile site the “New Ronneburg Landscape“ was the core zone of the national horticultural exhibition BUGA in 2007.

By implementing the above-mentioned measures, as well as by ongoing remedial operations and contracting out important projects to local entrepreneurs worth ca. 1.9 billion €, WISMUT contributes to safeguarding the existing jobs and creates new job opportunities throughout the region.

Achievement of walk-away status

Source term remediation and natural self-purification

Achievement of walk-away status is among the priority remediation goals – with regard to mining-originated contaminant releases into ground and surface water bodies. This may be the greatest challenge facing the WISMUT Environmental Restoration Programme in terms of environmental conservation. Most significant sources of contamination are the tailings management areas, the large-scale waste rock pile complexes and in particular the flooded underground mines. The sources, in many cases are unattainable, at least in the short-term. The large and persistent contamination potential of these sources results from (a) their size, (b) the high content of reactive materials, (c) the elevated degree of mechanical breakdown during mining and/or processing operations as well as from (d) the fact that the contained contaminant potential is chemically instable due to surface storage or large-scale groundwater drawdown, respectively. As a consequence of the above, the operation of active systems to collect and treat typical contaminated mine water is a requirement in order to comply with Maximum Contaminant Levels (MCL) of water-borne emissions.

Water management and conventional treatment of mine waters are by far the most cost-intensive long-term tasks of the WISMUT Environmental Restoration Programme. This is such because the volume of overflowing flood water is virtually beyond control and its quality changes very slowly, mainly through flushing and dilution. For that very reason, WISMUT had initiated early the investigation supporting in-situ techniques such as flooding underground mines with reactive material with the aim of immobilising the source the contaminants dissolved in the mine water, and at the same time reducing the resupply of contaminants from the rock face and thereby aiming for steady state conditions that would come as close as possible to pre-mining characterised by minimum material flows. With this approach, a host of options was investigated, some of which need to be developed to industrial scale including (a) in situ neutralisation of flood water with lime, (b) introducing neutralising/reactive solids into the mine (placement of underground reactive barriers), (c) stimulation of naturally occurring microorganisms, (d) controlled barite precipitation in pore space with coprecipitation of contaminants, (e) purposeful management of mine water flow components for oxidative precipitation/coprecipitation or (f) the introduction of elementary iron (Paul et al. 2006, Wismut 2010).

However, industrial scale applications are still hampered by a multitude of difficulties. The most serious are:

- Limited system understanding and uncertain long-term behaviour, insufficient knowledge of flow conditions within the mine and lack of or limited storage room for precipitates/reaction products;
- Limited accessibility of the overall system for technical measures and process control;
- Insufficient or uncertain efficiency;
- Reverse reactions of contaminants with diverging geochemical behaviour (U, As, Ra, Fe).

Irrespective of these difficulties, development of a fluid injection technique for the Königstein mine is under way which is to be used during final mine flooding.

The replacement of water treatment plants by passive biological systems is for now faced with limiting factors, in particular elevated contaminant loads and the complexity of mine water qualities. Constructed in 2003 at the Pöhla site, a passive biological plant has had limited success for the treatment of mine water. It was found that at the end of several years of test operation a stable operating procedure was achieved but the expected cost savings did not materialise.

The situation is less critical with regards to the release of air-borne emissions into the air. The shutdown of mine ventilation, mine flooding as well as final capping or at least interim covering of the major sections of the waste rock piles and tailings ponds have resulted in a sustainable reduction of air-borne contaminants at all sites. The Schlema-Alberoda is the only site where long-term active technical measures are required to maintain a low pressure gradient within the unflooded near-surface portions of the mine workings with the objective of preventing a deterioration of the radon emissions in the nearby town of Schlema.

Stability of emission barriers

The most successful type of emission barriers implemented in situ to remediate all waste rock piles and tailings management impoundment areas are vegetated surface covers made of natural mineral soils (*vegetated soil covers*). The total surface area of all sites to be covered is in excess of 1,100 ha. Performance requirements of the cover are identified on an site-specific basis and are determined first and foremost by the existing contaminant potential of the site to be remediated, the relevant emission pathways as well as by the intended use of the site following remediation. The most important consideration to be taken into account in the cover designs for waste rock piles and tailings ponds include the (a) reduction of infiltration, (b) limitation of radioactive/non-radioactive emissions, (c) guarantee of physical stability and protection against erosion as well as (d) promotion of vegetation.

Since all soil material covers are subject to many environmental factors such as freezing/thawing cycles, and root advancement / bioturbation, their effect on cover performance has to be taken into consideration as early as in the planning stage. Comprehensive knowledge of the interaction between the vegetation and the water balance of the moisture retention layer is of key importance. For the placement of highly compacted layers of low permeability material, a sufficient thick moisture retention layer has turned out to be essential to ensure its long-term performance. It has been found that local conditions at the WISMUT sites require a minimum thickness of 1.5 m of a moisture retention layer. Since the construction of cover systems of such thicknesses require considerable effort and resources, attempts were made at a number of sites to attain remedial goals by applying covers known as the moisture storage – evaporation concept.

Woodland extension

In Central Europe, the end stadium of uncontrolled vegetation growth invariably results in the establishment of woodland. In line with sustainability, almost half of the remediated WISMUT areas are devoted to forestry reuse. Such reuse for forestry purposes includes the establishment of tree and forest stands which are compatible with local conditions. In many cases, this provides the best guarantee for the emergence of a stable ecosystem which once solidly established requires little maintenance. As well, purposeful afforestation of cover systems may serve as a supportive medium to minimise infiltration. For the backfilled former Lichtenberg open pit, the predominant afforestation was perceived as an integral part of the overall remediation measure since dense, water consuming and productive forest vegetation constitutes an optimum option in terms of cost optimisation and to ensure long-term radiation protection performance of the waste rock cover. 70 % of the covered landscape is devoted to afforestation as the reuse option. Forest effect on water balance is obvious: woodland drastically diminishes groundwater recharge in comparison to open range landscape and this is accomplished entirely without the maintenance of technical barriers. In this respect, coniferous species provide particular advantages due to their year-round interception and transpiration effect.

During vegetation establishment on the remediated areas, emphasis is on mixed stands of high diversity pioneer species including essential species of potentially natural vegetation establishment. Stand development goals for the Lichtenberg pit, included to a large extent the dominant durmast oak species, but also coniferous species such as larch and Scots pine. Promising rooting results on test areas of oak and pine species had proven their suitability for the site. The enormous rooting capabilities of the oak tree ensure a stable development of stands even under strongly varying water balance conditions. Under the climatic conditions prevailing at the Ronneburg site, the establishment of a more or less dense forest vegetation will achieve average groundwater recharge rates in the order of 10 to 15 % of the adjusted regional precipitation rate.

Nature conservation and protection of species

The return of formally devastated areas to nature was a considerable achievement of the WISMUT Project. In fact, by their size and location, many areas can assure important functions within the biotope network of the surrounding environment and hence provide a new habitat to a considerable number of endangered and protected plant and animal species.

Documentation, preservation of know-how and information management
Following the completion of the physical remediation projects, contaminant release potential will still remain at the sites, in particular at remediated waste rock piles and tailings management areas. Such sites will only qualify for limited reuse. As a consequence, they are subjected to permanent institutional control in order to ensure that the integrity of the chosen remedial solution will be safe from damage caused by lack of knowledge or any other reason. This applies to both radiation protection and protection of water resources as well as to mine subsidence and geomechanical aspects. It is therefore a prerequisite for the sustainable safeguarding of the remedial success that relevant technical data and information be stored permanently with efficient access opportunities for short- and long-term use. The scope of information required for that purpose does not only include site-specific documentation of the completed remedial work and of the remedial success, but also information on remaining/disposed contaminants and on the selected barrier systems. Documentation on environmental impacts in connection with all remediated sites as well as the preservation of documentation allowing know-how of the complex system relationships at the respective site is also made available.

The WISMUT information and documentation system currently under development stores analogue documents and electronic data as well as information gathered during the monitoring and evaluation phases of the sites.

Safeguarding of remediation results and long-term tasks

According to current planning, key remediation projects are expected to be completed by the year 2020. After that, long-term after-care activities become indispensable in order to sustainably safeguard the remedial success.

Among the long-term tasks to be addressed in the post-remedial period, the following categories are of particular significance: (a) real estate management, care and maintenance of sites with permanent use restrictions, in particular with regard to the integrity of capping and other technical equipment, (b) treatment of contaminated flood water and seepage, (c) securing of remaining underground mine voids and subsidence damage repair, (d) environmental monitoring, as well as (e) data and know-how management.
Current work and financial planning with regard to long-term tasks is based on a forecast covering the period until the year 2040. According to current estimates, the treatment of contaminated flood waters and seepage will absorb more than 70 % of

the financial resources earmarked for the long-term. Operation of water treatment plants at the Schlema, Ronneburg, Pöhla, Seelingstädt and Helmsdorf sites is currently expected to continue during the entire period. For that reason WISMUT has particular interest in identifying potential reclamation options for optimisation and savings.

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