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Environmental Remediation of the Wismut Legacy and Utilization of the Reclaimed Areas, Waste Rock Piles and Tailings Ponds.

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Abstract

Between 1945 and reunification (1989) of Germany more than 232 000 t of U_3O_8 has been produced in Saxony and Thuringia, East Germany. This affected an area of approximately 100 km^2 and left behind an extensive legacy of contaminated operations areas, underground and open pit mines, waste rock piles and tailings ponds. Following reunification, DM 13 billion (€ 6.6 billion) were committed (and later revised to € 6.2 billion) to remediation of the liabilities and the government owned corporation, Wismut GmbH entrusted with the implementation of the Environmental Remediation (ER) of the liabilities. The prime goal of the ER Project follows from the legal requirements to abate health risks, mitigate existing and prevent future environmental damages.

During the investigations and assessment of risks, development of remediation concepts, adoption of suitable technologies and work procedures as well as physical implementation of the remedial measures extensive use was made of international (mostly US and Canadian) ER experience. The extent of remedial measures was based on object-specific Environmental Assessments rather than on uniformly applied health/environmental standards. The ER workflow is more an iterative process than a linear succession of tasks, such as common for civil engineering projects. The internal (technical) parts of the problems were partly resolved by using Conceptual Site Models (CSM) for selection and prioritization of remedial measures. Reclamation of the waste rock piles is by covering in situ, relocation to a central pile or backfilling into an open pit. The backfilling of the open pit at Ronneburg with acid generating waste rock has been optimized from a geochemical point of view. For tailings ponds reclamation in form of dry landforms is being followed. To increase release (and reuse) of scrap metal from demolition, a fast and reliable method of discrimination of the non-contaminated metal has been developed. The flooding of underground mines is carried out in a controlled way. Both the reclamation works and the environmental base line are subject to thorough monitoring. An important part of emissions control is the monitoring of the seepage from waste rock dumps, discharges from the tailings ponds and of the discharge from mine flooding. The numerous decentralized on site data basis are accessed at the corporate level by means of an ORACLE based holding data base, which allows fast overviews, specific data quires and overlaying of different types of information and data to answer multifaceted questions.

Utilization of the reclaimed areas and objects is becoming an important part of the considerations in the present phase of the project. This is due to the fact that the Wismut legacy is located in former mining districts, which are presently depressed and ER is an important factor in creation of an environment conducive to economic revival and infrastructure development. Concerning utilization, there are no legal restrictions placed on areas completely cleaned up of contamination. The utilization of partly reclaimed areas, waste rock piles and tailings ponds is regulated and restricted to settlement of industry and trades or to forestation. Exemptions, however, are possible if the owner takes on the responsibility for long term monitoring and maintenance. Successful examples of integration of reclamation plans and communal development are provided by rebirth of the health spa in Schlema and by the former mining town of Ronneburg expected to host the Federal Garden and Landscape Exhibition in 2007 (BUGA 2007).

Background

Between 1945 and reunification of Germany (1989) more than 232 000 t of U_3O_8 has been produced in Saxony and Thuringia, East Germany. The mining and milling sites are in Fig. 1.

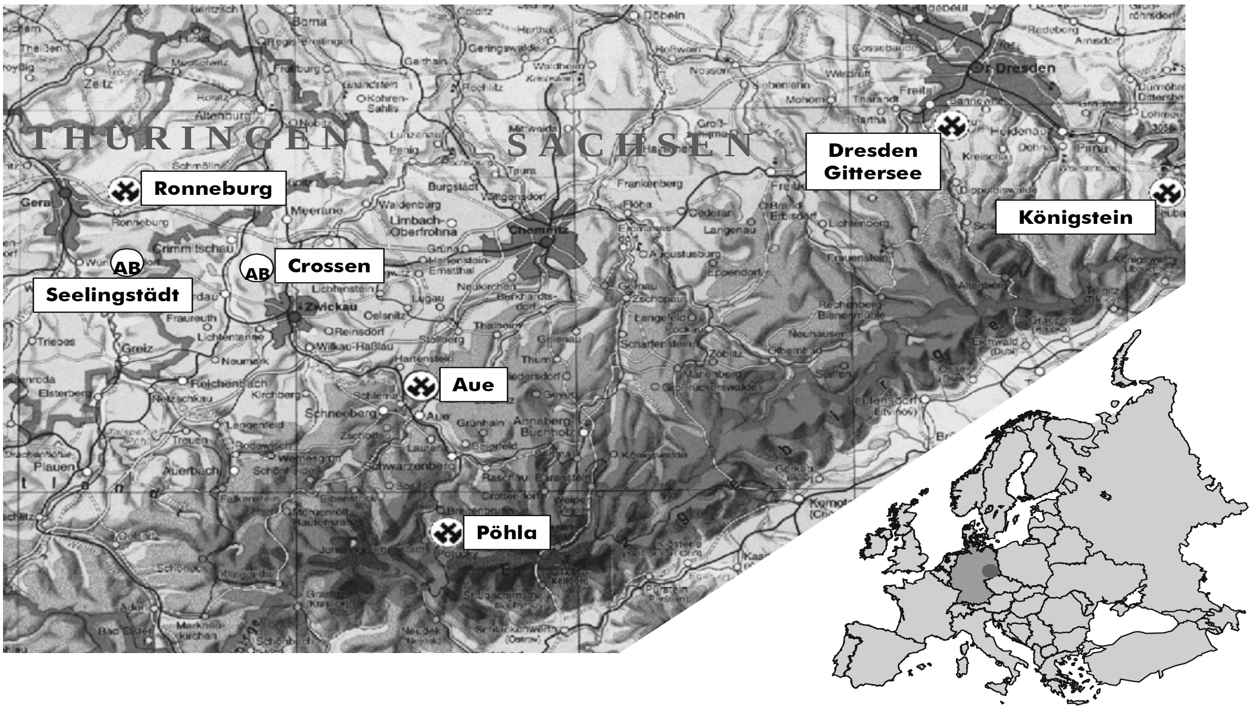

Figure 1. Mining and milling sites of Wismut

The mining and milling operations affected an area of approximately 100 km^2 and left behind the “worst” uranium mining related legacy in the world. At the time of closure of production in December 1990, the inventory of contaminated areas and objects comprised the following scope of liabilities:

Operations areas (37 km^2), five (5) large underground mines, an open pit mine (84 M m^3), waste rock dumps (311 M m^3) and tailings (160 M m^3). The associated specific activities are 0.5 to 1 Bq/g for the waste rock and 10 Bq/g for the tailings.

To deal with this legacy, a special “Wismut Act” has been passed in the Federal Parliament, December 1991, which opened opening the road to the environmental remediation. The Federal Government committed DM 13 billion (€ 6.6 billion) for the purpose (the sum was later revised to € 6.2 billion) and established the present day Wismut GmbH, which was entrusted with the implementation of the Environmental Remediation (ER) program.

The prime goals of remediation follow from the legal requirements of the “Federal Mining Law” (*BbergG*) and “Ordinance for provision of radiation protection for waste rock dumps and industrial settlement ponds and for use of materials deposited therein” (*HaldAO*) stipulating the general obligation to abate health risks, mitigate existing and prevent future environmental damages after mine closure and regulating the specific features of uranium mine closure.

In the initial phase there was no adequate experience available in Germany regarding uranium mine closure. In order to commence the ER Program without delay, extensive use has been made of the international experience available in the field. Cooperation was sought with the UMTRA Project in US and the relevant institutions and companies in Canada[1]. Regular workshops organized by Wismut and meetings of the Uranium Mine Remediation and Exchange Group, UMREG served the purpose of international peer review of the solutions, concepts and technologies adopted and/or developed at Wismut. The present paper focuses on the highlights of the specific solutions and technologies developed at Wismut since, which are likely to be of relevance to other ER projects.

Reclamation

The remediation process. In 1990, in course of a preliminary survey by gamma rate measurements, the extent and level of contamination within the territory potentially "affected" by the mining/milling activities was appraised. For about 85 % of the "affected" territory the survey showed radiation levels close to background, thus allowing a release of these areas for unrestricted utilisation.
After initial survey, the ER work focused on the five mining sites (Ronneburg, Aue/Schlema, Poehla, Koenigstein, Gittersee and two milling sites, Seelingstädt and Crossen). Remediation concepts were prepared for each of the sites with the goal of achieving compliance with the legal requirements of the Mining Law and of the Radiation Protection Ordinance. Most of these requirements could be satisfied by straightforward technical measures such as, reshaping of the areas, waste rock piles and tailings ponds to a stabile form, excavation and relocation of contaminated materials, containment of contaminants by placement of covers, provision of runoff and erosion protection and treatment of discharges.
The remedial work is being implemented in 14 projects coordinated from 3 on site Management Units (Ronneburg, Aue and Königstein). The strategic direction, feedback, optimization and specialists support is provided from the Head Office in Chemnitz. Presently, approximately two thirds of the work has been completed.

The preparation of specific remedial measures begins with an object-specific Environmental Assessment, which determines the extent of remedial works. In agreement with the permitting authorities, preference was given to this approach over the use of uniformly administered prescriptive environmental criteria, because the object-specific approach relates the extent of remediation to the actual size of the risk presented by a contaminated area or object.

The effective individual dose, calculated for realistic release and uptake scenarios serves as the measure of the risk. If the calculated dose in excess of the background level exceeds the 1 mSv per year limit recommended by the International Commission for Radiation Protection, ICRP, the remedial measure is selected such to ensure (under consideration of costs and benefits) compliance with the 1 mSv per year criterion. The final specification of the remedial measures in addition considers the regulated conventional contamination criteria as well.

[1] A Memorandum of Understanding was signed with the Canadian Ministry of Mines and Natural Resources, MNMR and with Atomic Energy Control Board, AECB (the predecessor of the present Canadian Nuclear Safety Commission, CNSC), May 1991.

The implementation of the remedial measures turned out to be an iterative process rather than a linear succession of tasks, such as common for civil engineering projects, Fig. 2 [1].

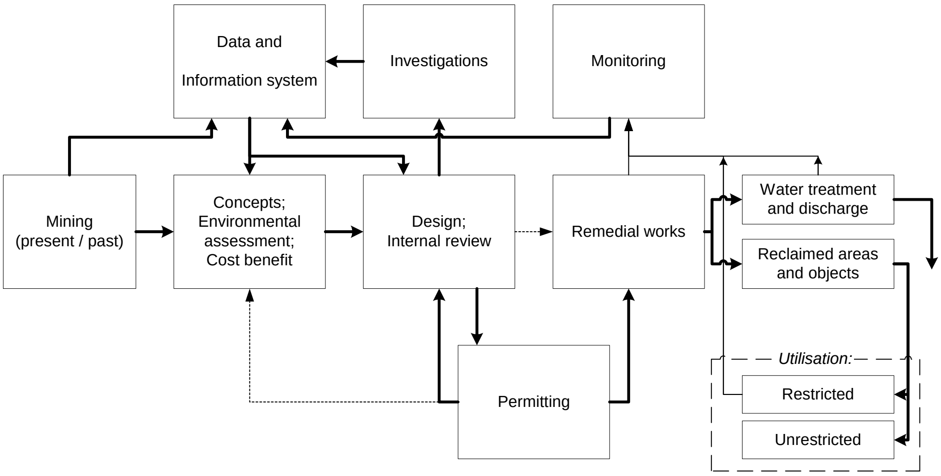

Figure 2 Work/information flow in the Wismut remediation project and products of the remediation

The delays in the remedial workflow occur mainly due to the feedback loop created by the regulatory process but sometimes also due to inadequate knowledge of interdependencies among contaminants sources collocated on the same site; This situation usually requires additional investigations if an optimized solution is to be implemented. For minimisation of the delays due to need of additional data and for prioritization of the required remedial investigations and measures the use of a Conceptual Site Model (CSM) proved to be very helpful [2].

Contaminated areas. The aim during reclamation of the contaminated areas is (whenever feasible) to maximize the number and size of areas which can receive a complete clean up.

Waste rock. Reclamation of waste rock piles is either by stabilisation and covering *in situ* or by relocation to a central pile/into the open pit mine.

At Ronneburg, the waste rock piles located close to the surface mine provide the material for backfilling of the open pit. The backfilling procedure has been developed jointly with Canadian companies and follows the strategy of putting the waste rock with the highest acid generating potential (i.e. with high pyrite content) on the bottom of the pit into a zone, which will be below the groundwater level anticipated after flooding of the underground and surface mines; This placement strategy will prevent the oxidation of the acid generating minerals and thus, the development of acidic seepage [3]; Waste rock containing an overabundance of alkaline minerals is placed in the upper part (zone) of the pit, Fig. 3.

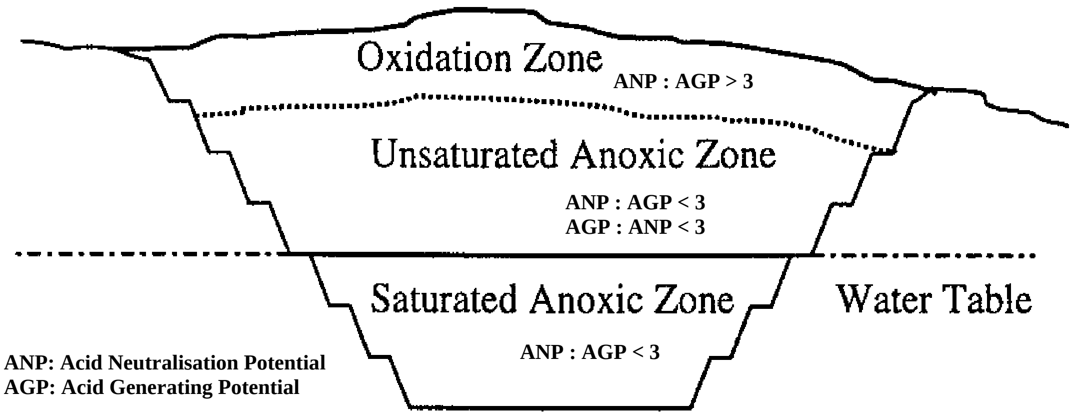

Fig. 3 Backfilling strategy of the open pit mine at Ronneburg. Acid generating waste rock is placed in the saturated anoxic zone, neutral waste rock in the unsaturated anoxic zone and alkaline waste rock into the oxidation zone.

Following the described procedure, approximately 40,000 tons per day of waste rock are relocated into the pit.

In case of *in situ* remediation of the waste rock piles, the piles (after reshaping) receive a soil cover designed to reduce radiation, radon exhalation and limit infiltration into the pile; Similarly, the landform of the backfilled open pit mine will be capped with a soil cover as well.

Tailings ponds. The tailings ponds of Wismut are being reclaimed as dry landforms. The decision in favour of this option was based on a probabilistic risk assessment of the equivalent costs of remediation (including costs of stewardship) of the water capped and of the dry landform remedial solutions. If the additional costs arising with a probability of 35 % or less (i.e. in the long term) are included in the assessment, the economic performance of the dry reclamation is better than the water capped solution (an option implemented at Elliot Lake), which performs better up to 65% of probability of additional costs (i.e. in the short and mid term), Figure 4 [4].

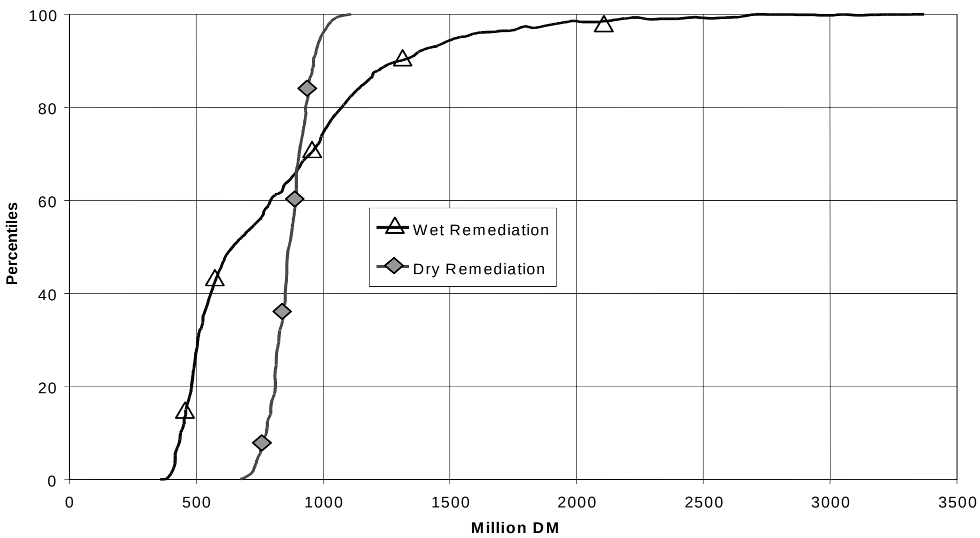

Fig. 4 Equivalent Costs for the Wet and Dry Tailings Reclamation options for the Helmsdorf tailings pond.

From the technological point of view the most challenging part of the dry reclamation approach is to find suitable stabilisation technologies for the soft, under-consolidated slimes having very low shear strength, thus making access of earthmoving machines impossible. The stabilization methods viable for various ranges of shear strength were specified jointly with specialists of Syncrude, Figure 5 [5].

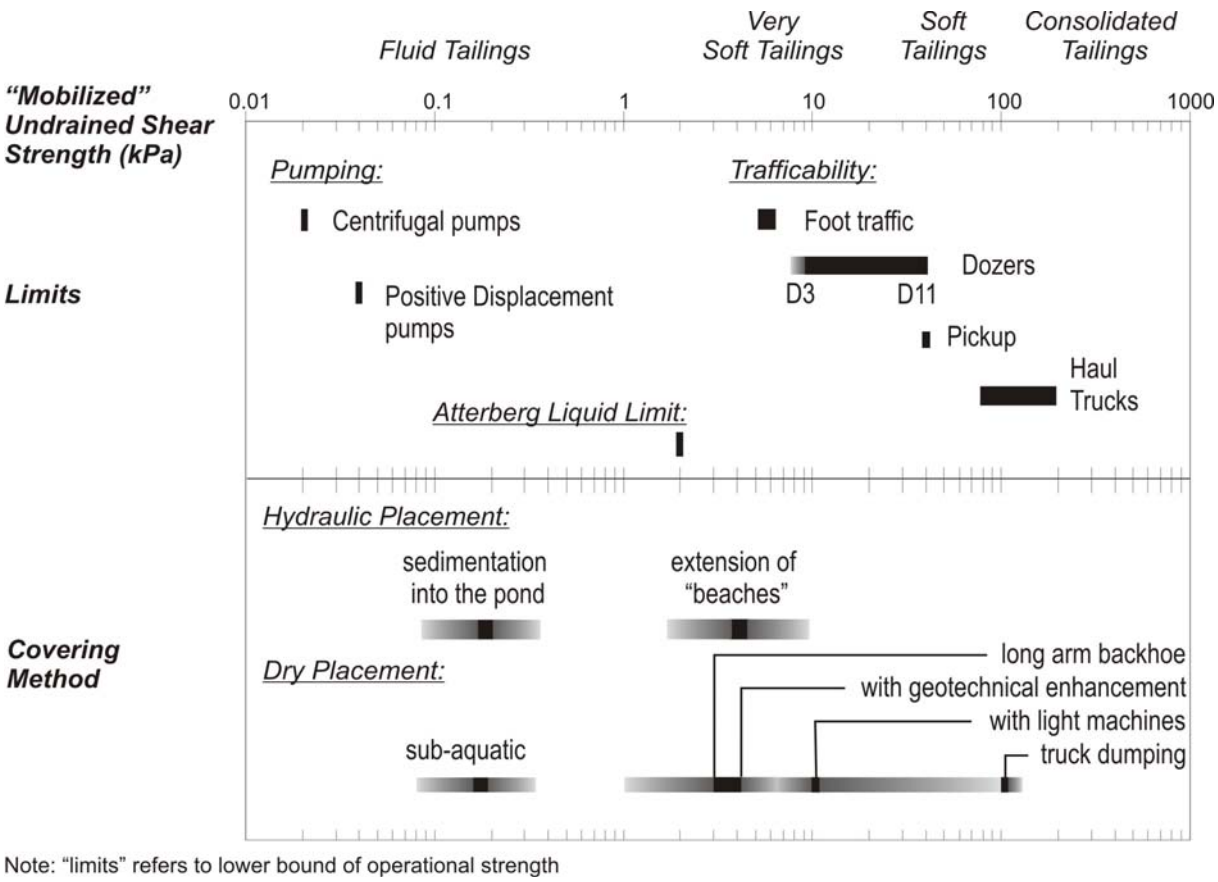

Figure 5 Suitability of tailings stabilisation technologies

Robustness of covers against erosion. An exhaustive overview and international comparison of the suitable cover types has been presented at UMREG 2002 [6]. From a number of covers built by Wismut, a 1 m thick, two-layer cover system emulating the natural soils of the mountainous area of Aue - Schlema (Fig. 6) underwent an unplanned performance test concerning erosion during the extreme rainstorm of August 12 to 13, 2002.

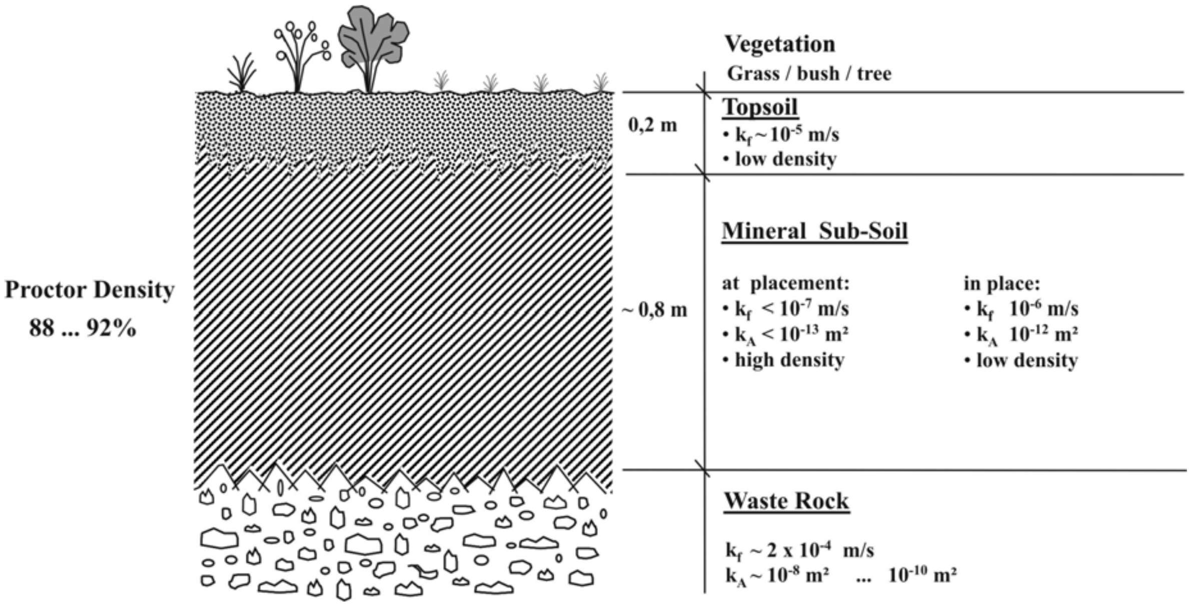

Figure 6 A two-layer cover system emulating natural soils used at Schlema

The cover, which was placed on a steep slope (1 : 2 to 1 : 2.5) and vegetated with grass proved to be able to withstand a precipitation event, which was a multiple of the hundred years precipitation in the region and was rated as the highest rainfall event to be expected in thousand years.

Radon attenuation of covers. A novel type of assessment of long-term radon attenuation of covers has been established at Wismut [7]. The method is based on measurement of lead (Pb-210) traces below and above the cover-object (waste rock or tailings) boundary[2].
In a well sealing cover most of the radon decays into Pb-210 after a penetration depth of 1 to 5 cm. The lead traces show discernibly positive values and the sum of the specific activities of the lead traces below and above the cover-object boundary is positive.

In a less well sealing cover, the positive lead traces above the cover-object boundary are weak (little accumulation of Pb-210) and the lead traces in the tailings or waste rock are strongly negative due weak attenuation of radon transported toward the cover. The sum of the specific activities below and above the boundary is negative.

Figure 7 shows the performance of inadequate tailings cover, which had been constructed more than 30 years ago. The thickness of the cover is 50 cm and consists of a single mineral layer. The lead traces measured are clearly negative, evidencing that a 50 cm cover layer of the sandy material used is insufficient for adequate radon attenuation.

[2] The lead traces Pb (z) are estimated as the depth-dependent differences of the specific activities of Pb-210 and Ra-226 in a soil cover layer: $Pb(z) = A_{Pb\text{-}210}(z) - A_{Ra\text{-}226}(z)$

The method is primarily suitable for testing of old covers (> 30 a) and is based on growth of Pb-210 ($t_{1/2}$ = 22 a), which (after several short-lived nuclides from Rn-222 ($t_{1/2}$ = 3,8 d)) is the direct daughter product of Ra-226 ($t_{1/2}$ = 1590 a).

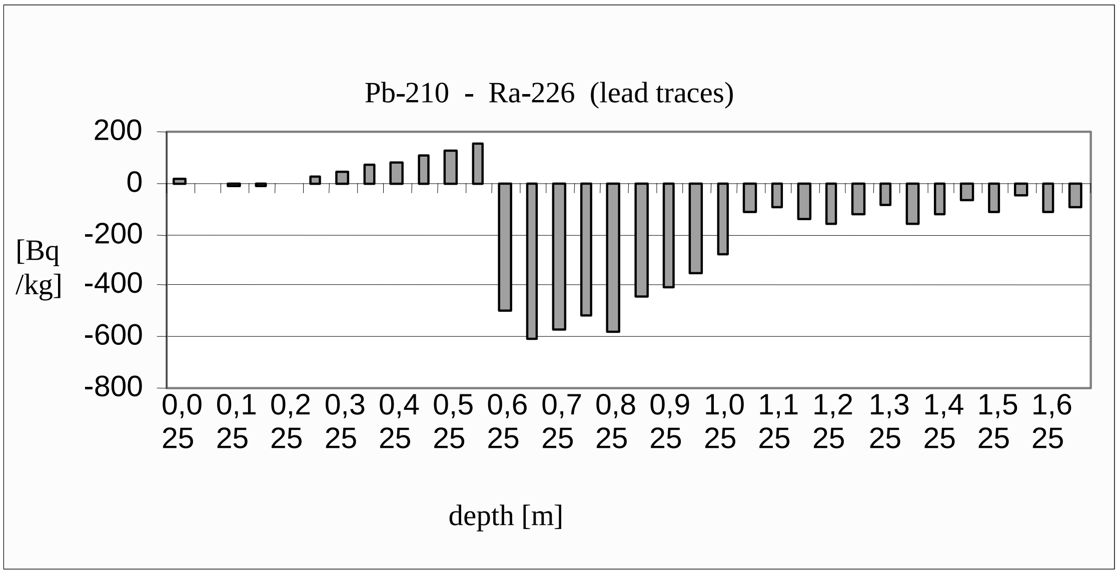

Fig. 7: Distribution of lead traces in a cover- tailings system at Lengenfeld. The cover has been built in 1970s (>30 years ago).

Flooding of mines. The mine flooding is done in a controlled way to prevent contamination of surface water bodies and of utilized aquifers [8]. Mine water discharges are in order of 50 to 1000 m^3/h, depending on the size of the mine. Other discharges in need of treatment arise from dewatering of tailings ponds (several hundreds m^3/h) and from waste rock dump seepages (1 to 30 m^3/h). The water treatment residues (containing approximately 500Bq/g) are disposed off into waste rock piles and tailings ponds.

Observations of mine discharges, which present the largest source of contaminated water, indicate that the initial peak load of contaminants decreases with time more or less exponentially [9]. After the peak load is over, the treatment requirements radically decrease as well. To maintain the economic efficiency of water treatment, Wisutec GmbH, a commercial daughter of Wismut, currently tests a number of alternative treatment methods including wetlands.

Scrap metal. During remediation, considerable amounts of contaminated debris and scrap metals arise from demolition of structures. The contaminated metal components have a total alpha surface activity (TAA) in the range of mBq/cm^2 to Bq/cm^2 (of U-238 and daughters). The contaminated and non-contaminated scrap metal is usually intermixed in unsorted heaps, providing typically a contamination distribution as presented in Fig. 8.

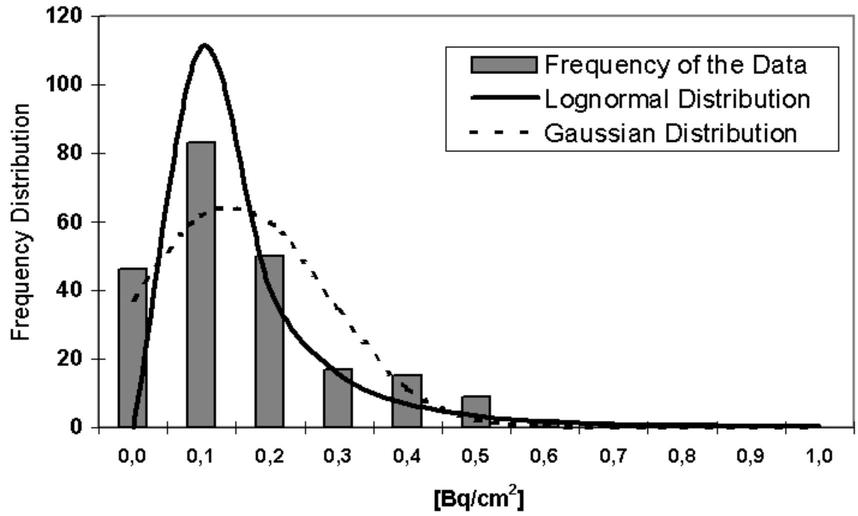

Figure 8 Typical contamination frequency distribution of TAA values in a scrap metal heap at WISMUT.

The separation of the non-contaminated metal, which can be recycled, requires a reliable discrimination from the contaminated material. To improve selectivity while continues using the standard portable, large surface (beta) contamination monitors in the field, a sophisticated method of calibration has been introduced. Based on the operational history of the particular facility and/or equipment dismantled, the level of contamination is pre-categorized and the anticipated nuclide vector and index nuclide established in the laboratory. The field instruments are calibrated against the laboratory measurements of the specific waste type prior to the field campaign. Using this procedure, the estimation of TAA from the measured beta-count rate proved to be feasible with the required accuracy.

The decision regarding release or disposal of the scrap metal is based on the comparison of the TAA reference value (0.5 Bq/cm^2) with the upper limit of the confidence interval (95 % confidence value) applicable to the particular contaminated scrap metal heap.
The contaminated metal, which cannot be released, is disposed off into tailings ponds, open pit backfill or waste rock piles. It has been shown that the risk potential of these objects increase only marginally due to this disposal.

Data Management. During remediation a large variety of detached and very heterogeneous databases came into existence at the working level. To make these data and information available corporate wide for fast overviews, specific data quires and for answering multifaceted questions, which require the overlaying of different types of information and data, a data integration tool capable of accessing the various data bases was required. The typical data and information existing at the working level comprise documents, photographs, object-related data, monitoring and measurement data and digital maps, geo-referenced aerial survey photographs.
The solution was realised by a web based access to the data/information stored in the individual databanks and the integration of the required data in a holding databank on a central ORACLE based server (Fig. 9).

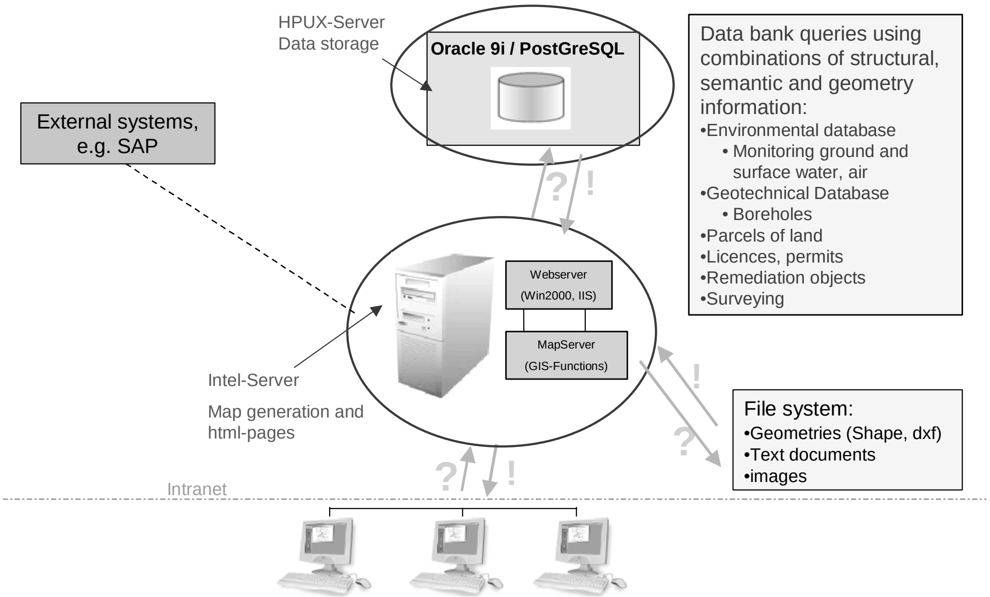

Figure 9 Technical Data and Information management system used to integrate detached heterogeneous databases.

Typical GIS-tasks (e.g. locator and intersection functions) of geometry-based data (polygons of objects, locations of measurement points) are carried out rapidly using the capabilities of the databank.

The responsibility for management (including updating and QA) of the individual databanks is local. The access via inter-/intranet is in compliance with the (very stringent) data safety requirements. The users have access to a continuously updated GIS supported information system at all times and the only requirement on the user side is the availability of an internet explorer and of a fast internet access (DSL).

Monitoring. The remediation is subject to thorough monitoring of the environmental base line and monitoring of the remedial activities directly on spot. Besides measurements of radiation and of specific radionuclides it is particularly dusting, which is being closely monitored in course of remedial works. During dry periods sprinkling is applied at the working sites to control dusting.
Baseline monitoring comprises measurements of emissions and environmental impacts. An overview of the Wismut approach to monitoring along, with other international monitoring programs is provided in [10].

The effectiveness of the first remedial measures is best demonstrate by the following: Beginning of 1990 the Wismut discharges carried a uranium load of approximately 28 tons, which already 1998 decreased to less than 4 tons of uranium per year. The decrease since 1998 was less spectacular and presently is in the order of 3 t per year. A similar decrease pattern has been recorded for Ra-226: Early 1990 the discharges contained more than 23 000 MBq Ra-226, which was decreased to less than 300 MBq by early 2004.

Know-how transfer. In course of the remediation a considerable degree of work standardization has been achieved and since 1995 the remediation know-how has been applied in a large number of external projects, mainly in Central and Eastern European countries. The external activities mainly focused on (1) assistance with concept development, planning, engineering and procurement of works, (2) specialized training and education and (3) auditing and project monitoring [11]. Wisutec GmbH presently carries on these activities.

Post-remedial utilisation

The physical products of remediation (besides production of environmentally benign water) are the reclaimed land and rehabilitated waste rock piles and tailings ponds, which are candidates for further utilisation (unrestricted or restricted).

Concerning utilisation, both internal and external experience led us to conclude that

(a) the sustainability of the remediation results is best achieved if the future use of the reclaimed areas/objects has been specified prior to reclamation and

(b) the effect of environmental reclamation goes well beyond containment of the health and environmental risks and can greatly contribute to the regional revitalization and development.

In the same trade we believe that value added results can be achieved at no additional (or at reimbursable) costs, if reclamation is done with a well-defined utilization goal in mind [12].

To ensure sustainability, it is always attempted to develop the utilization goal in cooperation with the future user (i.e. municipality or developer) and regulatory authorities. If a consensus is achieved with the stakeholders in time, “reclamation by objectives” becomes practicable, i.e. the objectives for the individual remedial steps can be set consistent with the ultimate utilisation goal.

Concerning utilization, there are no legal restrictions placed on areas completely cleaned up of contamination. Considering the population density of Thuringia (154 inhabitants per km^2) and Saxony (247 inhabitants per km^2), there are usually no problems finding interested parties for the land, which had been completely cleaned-up.
However, given the high costs of a complete clean up and the relatively small risk presented by slightly contaminated areas, a remediation aiming for unrestricted utilisation cannot be justified in all cases. In line with the recommendations of the German Commission on Radiological Protection (SSK-92, volume 23) a partial reclamation is performed in such cases; The restricted utilisation usually implies that only settlement of industries is recommended.

The utilization of waste rock piles and tailings ponds is regulated by the “Ordinance for provision of radiation protection for waste rock dumps and industrial settlement ponds and for use of materials deposited therein, (HaldAO)”, which specifies forestation as the most eligible type of utilization. Although the utilisation in the above cases is restricted, exemptions to the recommended utilisation are possible, if the obligations for long term monitoring and maintenance can be satisfactorily settled. The economic objective under the exemption rule is to find a potential utilization, which could (at least) partly cover the costs of the long-term monitoring and maintenance.

Reclamation with the objective of implementation of a specific utilization often requires an extensive soil conditioning in addition to the “regular” remediation. We are of opinion that soil conditioning in these cases must not be viewed as additional costs but rather as the price for avoiding additional remedial measures at a later point.

Among the most common utilizations is forestation or establishment of green fields. Forestation has the advantage of being a low maintenance utilization option, which does not lead to additional costs in the long-term.

The rationale of searching for other, more creative types of utilization is their potential to act as seeds for further regional/communal development.
A good example of successful integration of reclamation and town (re-)development is provided by the city of Schlema, where recreational facilities, such as the health spa, parks, promenade, golf course, etc. were established on a backfilled and rehabilitated mine subsidence area and on rehabilitated waste rock piles.

Major impulses for the former mining towns of Ronneburg and Gera are expected to come from the Federal Garden and Landscape Exhibition in 2007 (BUGA 2007), the planning of which is closely related to the progress of reclamation works in the open pit mine located near the town of Ronneburg.

To facilitate post-remedial utilization, the reclaimed areas and objects are subjected to a final assessment during which the essential inventories and the “as built” status of remedial measures are documented. A concise record of this assessment in form of a database and the provision of a user friendly access to this information on the regional/communal level could enhance the development of feasible utilisation projects for the areas and objects reclaimed for restricted utilisation. In addition, the record could serve as an evidence of proficiency of the remedial measures taken and help with technical questions in case of potential repair and questions concerning liability.

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