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RADIOLOGICAL ASSESSMENT OF MINING RESIDUES AND SITES IN GERMANY

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1. National conditions requiring radiological assessment of mining sites

Mining and ore processing have a long history in the regions of Saxony, Thuringia and Saxony-Anhalt. The ores were often mineralized with uranium and therefore these residues of mining (e.g. dumps of mining debris, slags and others) and ore processing waste may present a radiological hazard, in particular if the residues from mining have been used as building material or former mining sites have been built up. Immediately after World War II, the Soviet Union began to develop her nuclear capability and the uranium deposits in the part of Germany occupied by the Soviet Union (e.g. near Aue and other places) were exploited by the Soviet-owned stock company SAG Wismut. At the beginning the exploitation was concentrated on existing mines which had been producing silver and other non-ferrous ores in former times. At that time there was no consideration of the harm to the employees and of the impact on the environment and the population arising from mining activities.

In the 50s and 60s the uranium production was extended to other parts of East Germany. Numerous mines, mills and other facilities were in operation, waste rock piles and tailings ponds of considerable dimension resulted. In 1954 the SAG Wismut was converted into a joint Soviet-German stock company (SDAG Wismut). On the basis of an agreement between the governments of the Soviet Union and the GDR in 1962 the SDAG Wismut was obliged to observe the German regulations.Nevertheless in handling and dumping waste from mining and milling the radiological protection standards were observed only slightly and large areas were radioactively contaminated. After the unification the uranium production was ceased for economic and other reasons and, based on the Wismut Act [1] 1991 the Wismut company was transferred into a corporation (Wismut GmbH). The task of this corporation is the decomissioning of the mines, mills and other facilities used by the SDAG Wismut and the restoration of sites. The Wismut GmbH is responsible for 31 shafts, one open pit mine, 64 big waste rock piles and 10 tailings basins.

In the period up to the 60s many facilities, tailings basins and waste rock piles were abandoned or decommissioned by Wismut and were passed over to other enterprises or to communities. Since at that time radiation exposure due to the waste of mining and milling was not yet an issue of any concern these residues have to be considered a source of serious radiation exposure in particular if waste and sites are used again. As silver and other non ferrous ores and certain types of hard coal can be mineralized with uranium, a serious radioactive contamination has to be considered for the sites where such ores and coal were mined and processed.

Since the radiation exposures result from operations conducted either under regulatory radiological protection control which is considered to be inadequate from the present point of view or prior to any or to appropriate regulations the exposure situation needs intervention.

2. Principles of radiological protection by intervention

Principles of radiological protection, i.e. justification and optimization in case of an intervention refer to the intervention measure. Any action to reduce a lasting exposure is usually termed remediation. A remediation is justified if the disadvantages associated with the measure are exceeded by the achievable benefit, i.e. the achievable dose reduction. Optimization of the remediation then is finding out those measure by means of which a maximum benefit is obtained at the lowest cost taking into account all other relevant aspects (e.g. social, economic and political aspects, acceptance by the public etc.).

the total radiological situation in the mining regions and to identify these residues and sites for which a remediation should be considered.

In 1991 the BfS developed the project „Registration, Investigation and Radiological Assessment of Mining Residues" with the intention of providing surveys on type and number of residues, their inventory of radioactivity, the extent of radioactive contamination and carrying out a classification of residues and sites. The residues and sites were to be divided into those for which any remediation could be excluded (non-relevant residues and sites) and those which had to be regarded as sources of radiation exposure of the public and for which remediations were to be considered (relevant residues and sites).

The criteria applied for the classification were taken from the SSK recommendations described above. The recommended criteria of 0.2 Bq $\cdot$ g^{-1} and 1 Bq $\cdot$ g^{-1} are key figures for the classification: if the specific activity of materials investigated exceeds the level of 1 Bq $\cdot$ g^{-1} the residue or site is classified as relevant, if the specific activity of material does not exceed the level of 0.2 Bq $\cdot$ g^{-1} the residue or site is classified as non-relevant. In the range between 0.2 Bq $\cdot$ g^{-1} and 1.0 Bq $\cdot$ g^{-1} the classification was carried out taking into account additional criteria, e.g. the volume of material dumped, the area occupied by dumped materials and aspects of use. Values for the local gamma dose rate were derived from the levels of specific activity (e.g. the level of 300 nSv $\cdot$ h^{-1} from the specific avtivity of 1 Bq $\cdot$ g^{-1} assuming that a cover on the residue is less than 10 cm) allowing an evaluation of the residues on the basis of local gamma dose rate measurements which can be simply carried out. These criteria were also applied in combination with the criteria for the volume of materials and the occupied area and, if any covers were existing, taking into account the thickness of the cover.

In view of the large number and scattering residues and sites under consideration, a step-wise procedure of investigations described in [6] and [7] has been developed for the project with the intention of excluding as quickly as possible the residues for which a remediation is definitely not required. As a first step of investigations 34 areas of former mining activities have been defined as "suspected areas" using information on regions where uranium ores and other ores with above-average concentrations of uranium were mined as well as regions where the terrestrial gamma radiation is increased in comparison with the average level. The total area of "suspicion" is about 1 500 km^2. For these areas, all existing data relevant to the radiological evaluation of mining residues and sites have been compiled. In this way about 8 000 mining residues of different kinds have been identified and registered in a data bank, most of them being waste rock piles. The total of areas covered by the residues amounts to about 73 km^2, the total of areas with above-average gamma radiation to about 170 km^2. Further investigations concentrated on these areas ("investigation areas"). A lot of the registered data and information were obsolete and did not permit the classification intended. Additional efforts to verify and complete the registered data and information were required. By field inspection the information on the state of objects, sites etc. were updated and the data and information needed for the assessment were checked, revised and completed, if required. Screening measurements of the local gamma dose rate were included in this verification procedure. Following the verification procedure, a first classification was made evaluating in particular the local gamma dose rate measurements. Already at that stage of investigation about 57 % of the residues and sites could be classified as "non-relevant". Within the scope of the Federal Project only the rest ("possibly relevant relics and sites") were investigated in greater detail and were subjected to specifically evolved measurement programmes. These final programmes provide comprehensive information about dimensions of contaminated areas, thickness of contaminated layers, concentrations and inventory of radioactivity, radioactivity released and spread (e.g. radioactivity in seepage waters), relevant pathways and radiation exposure to the public. Grounds adjacent to the relics were included in the investigations.

The field investigations of the project were finished in 1997. The evaluation of measurements and other data ascertained is still going on. Based on preliminary estimations the number of relevant residues or sites requiring site specific assessments will be 500, most of them are dumps of mining debris. It is evident that the scope of site specific assessments can be substantially decreased, in particular as the measurements now available for the relevant sites are sufficient for proper dose calculations and the site specific assessments can be concentrated on the

exceptional cases. However, costly inquiries about the habits of the population group affected should not be made in identifying the relevant pathways.

Parameter for dose calculations

The dose calculation has to be implemented for infants (1 year) and children (5 years) and for adults to identify the critical group. The age-groups are defined by the age-depending dose coefficients and by parameters describing the breathing rate, the occupancy times indoors and outdoors for certain scenarios and the annual consumption of food. Costly inquiries should be avoided in estimating the parameters, too, and „best estimated" figures should be applied for calculating the effective dose. Examples for such figures are listed in Table II.

Table II: **Examples of parameters recommeded for dose calculation**

	Occupancy rate (in h · a^{-1})		Annual ingestion (in kg)			
Age group	Occasional stay	Using the area (gardening, playing)	Water	Meat	Cereals	Soil
Infant	-	1000	250	10	10	-
Child	250	1000	440	40	80	0.2
Adult	100	1000	440	70	110	-

Consideration of natural background

For a realistic assessment the dose calculation should be based on measurements of the contamination. Since the reference level of an effective dose refers to exposures caused by radioactive contamination due to mining activities and the radionuclides to be considered are the same which occur naturally the natural background level has to be substracted from the measurement to avoid an overestimation. To minimize the expenditures in estimating the natural background levels the SSK recommends a three step procedure: First the calculation should be made based on the measurements without the subtraction of any background level. If the effective dose calculated exceeds the reference level, a generic level of environmental radioactivity recommended by the SSK should be subtracted and, if the exposure calculated in this way still exceeds the reference level, site specific levels should be estimated and applied to calculate the effective dose realistically.

4. Radiological assessment of mining residues and sites

Residues and sites in the possession of Wismut

The Wismut Act [1] prescribes that Wismut has to decommission the tailings basins, dumps and other facilities and to carry out remediations, if required. Therefore Wismut carries out the radiological assessments for each site or facility to justify the remediation. The assessment is made in the form of a dose calculation applying the approach recommended by the SSK. The criterion for the justification is the effective dose level of 1 mSv · a^{-1} established in the Ordinance for Nuclear Safety and Radiological Protection of the GDR - VOAS [5] which is in force for the decommissioning and remediation of residues and sites in the possession of Wismut. Although the VOAS only regulates the radiological protection in "planned practices" regulations generally applicable for radiological protection in mining and milling are included and can be applied to control decommissioning and remediation. The entire process is under the supervision of the authorities in the Federal States responsible for carrying out radiological protection.

Residues and sites from past mining activities

Unlike the Wismut sites information on the residues and sites due to the uranium production in the 40s and 50s and due to other ore mining in the past was incomplete since this problem was poorly investigated in the past. A decision to generally consider remediations for all these sites had resulted in site specific assessments for some thousands of waste heaps and other sites possibly contaminated and required a lot of investigations, time and money. Therefore the Federal Ministry decided to carry out an investigation programme to provide a comprehensive survey on

3. Principles and criteria of justification for the remediation of mining residues and sites in Germany

In principle, the decision on the necessity of a remediation can be made by applying a cost-benefit-analysis for each site of interest. This approach is very costly because of the numerous aspects to be accounted for and in many cases it is more appropriate to establish reference levels (action levels). From the regulatory point of view the last mentioned approach is the only practicable way if decisions have to be made for a great number of sites of similar radiological characteristics.

Considering the situation in the mining regions the German Commission on Radiological Protection (SSK) recommends an effective dose level of 1 mSv $\cdot$ a^{-1} for the use of areas, buildings and dumps radioactively contaminated by mining in addition to the natural background level [2]. If the exposure due to the residue (e.g. contaminated ground, dump) does not exceed this level a remediation is not justified, otherwise a remediation has to be considered. In addition the SSK recommends in [2] measurable quantities as criteria. They fulfil the dose criterion and can be applied in deciding on the use of land on the basis of measurements only.

Table I: **Criteria for unrestricted and restricted use of land**

Specific activity of soil [Bq Ra-226 per g]	Use
< 0.2	unrestricted
< 1.0	restricted taking into account conditions, e.g. local gamma dose rate < 300 nSv $\cdot$ h^{-1} for use as industrial site
> 1.0	site specific decisions on use

These criteria are also intended to enable a distinction to be made between areas which do not, and areas which might potentially require a remediation.

For the exposure to radon the SSK recommends separate criteria for the justification and for the identification of sites for which a site specific assessment should be made [3]. If the radon concentration measured outdoors exceeds 80 Bq $\cdot$ m^{-3} (the upper end of the geogenic concentration range in the mining areas) a site specific investigation has to be made to estimate the contribution to the outdoor level due to the emission of the residue. If the contribution exceeds 50 Bq $\cdot$ m^{-3} a remediation should be considered.

When applying the measurable quantities a two-step procedure can be made for the justification of the remediation: If the measurements exceed these criteria site specific assessments have to be made and if these assessments result in an effective dose of > 1 mSv $\cdot$ a^{-1} or a radon concentration of > 50 Bq $\cdot$ m^{-3} a remediation is justified.

In [2] the SSK recommends for the demonstration „that the effective dose level is not exceeded in case of a given contamination, conditions must be assumed as realistic as possible but sufficiently conservative". The demand for realistic calculations of an effective dose must be observed strictly, otherwise purely hypothetical exposures will be eliminated and that would be a waste of money. In [4] the SSK provides an approach to the dose calculation that can be applied practically. To demonstrate how this requirement is translated into instructions for dose calculation the following examples can be discussed:

Relevant exposure pathways

For calculating „realistic" doses in intervention situations it is obvious that only actually existing scenarios and pathways must be taken into account. Therefore in [4] exposure pathways are listed which are generally to be considered „relevant". The SSK stresses that the actually relevant pathways for the case of interest should be selected from these. On the other hand the SSK recommends that additional pathways are included in the calculation procedure if appropriate in

identification of the really relevant pathways. Currently an ordinance is in preparation for regulating the radiological protection in connection with mining and other industrial residues. It will establish the criterion to be applied for the justification of the remediation of these sites and will regulate the responsibility for the site specific assessments and for the implementation of remediations. The criterion for the justification will be an effective dose level, the figure of which is still under discussion.

References

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