EXEMPTION LIMITS FOR CONTAMINATED MATERIALS TO BE RECYCLED AND FOR LOW LEVEL RADIOACTIVE WASTE FROM NUCLEAR POWER STATIONS AND URANIUM MINING AND MILLING AREAS IN SOUTH-EASTERN GERMANY

Rudolf Neider
Federal Institute for Materials Research and Testing
Berlin

ABSTRACT

For more than 5 years the Radiation Protection Commission (SSK) advising the Federal Minister for Environment, Nature Protection and Reactor Safety has been discussing the question of exemption limits for the very low level radioactive waste and for materials to be recycled which are contaminated on a very low level. The first recommendation was published in 1988 giving radiological protection principles for recycling and reuse of low level radioactive steel and iron arising from the maintenance, refurbishment and decommissioning of nuclear power stations.

Several other recommendations were given in 1991 to be applied in the course of decommissioning and redevelopment of the installations and sites left behind in the areas where uranium mining and milling took place in South-East Germany during the last 50 years. It was distinguished between cases where the circumstances and extent of radiation exposure of the population can be determined by the conditions of release of low level contaminated materials on one hand and those where preexisting situations are given on the other hand. This is the case e. g. in the sites of uranium mining and milling where areas and buildings are contaminated and it has to be decided which level of contamination will be tolerable and above which measures have to be taken in order to decrease the contamination and resulting exposure to the population. The permissible dose to the population in the first case should not exceed some 10 μSv/a while in the second case of preexisting situations 1 mSv/a is taken as maximum permissible dose to the population. The release limits given vary be-tween 0.1 and 1 Bq/g for the specific activities and 0.05 and 0.5 Bq/cm^2 for the surface activity.

In order to find out which release limits for low level radioactive waste should be applied in order to dispose it as if it were non radioactive environmental studies were performed. The resulting annual dose for members of the public should not exceed 10 μSv. The calculation was done for a great variety of radionuclides. In most cases the results are in agreement with the presently recommended release limits from 0.5 to 500 Bq/g depending on the radiotoxicity of the radionuclide concerned.

INTRODUCTION

Table I lists several reactor installations which have been shut down since 1971, for some of them decommissioning operations were already started (1). In the course of decommissioning there arise big amounts of scrap, rubble and waste which might be contaminated to a very low level of radioactivity only. Also complete components of the plant like pumps, valves and electric motors are to be disposed off or reused. It is estimated that during the decommissioning of a 1000 MW nuclear power plant about 10000 Mg scrap arise which are contaminated on a very low level only and a great part of this might be recycled or reused.

Table II lists installations in the south-east of Germany which were used since 1945 for uranium mining and milling operations (2). They were operated by the Sowjet-German corporation Wismut. Since 1945 about 220000 Mg of uranium have been produced in that area. All installations are to be decommissioned and areas are to be redeveloped. In the course of these actions there will arise enormous amounts of used apparatuses, scrap, rubble and tailings from the uranium milling activities. There are many buildings and areas in this sites, which after redevelopment should be reused for other purposes.

The release of materials and reuse of buildings and areas requires decisions about levels of specific activities and surface activities below which the possible radiation exposure to people is combined with such a low risk that no radiation protection measures are necessary, which means that all these objects would be below regulatory concern.

GENERAL RADIATION PROTECTION PRINCIPLES FOR THE ESTABLISHMENT OF EXEMPTION LIMITS

For the recycle and reuse of steel and iron scrap from nuclear installation the German Radiation Protection Commission requires that in order to minimize the exposure of the public by recycled or reused materials from NPP's the first option should be to recycle and reuse scrap and other materials within the nuclear field as far as possible (3). This is practiced already in Germany to some extent by melting the scrap and recycling the produced materials in the nuclear field e. g. as transport and storage containers or as shielding blocks. In all those cases where this is not possible for technical or economical reasons the "Principles for Exemption of Radiation Sources and Practices from Regular Control" established by the IAEA are applied (4). These require that from a radiation protection standpoint two basic criteria should be applied to determine whether or not a practice can be candidate for an exemption from the Basic Safety Standards:

- individual risks must be sufficiently low as not to warrant regulatory concern and
- radiation protection including the cost of regulatory control must be optimized.

For the first criteria the concept of trivial level of risk or dose is applied. The conclusion is that an individual radiation

TABLE I

Nuclear Power Plants to be Decommissioned in Germany (1)

NPP	Start	Shutdown	Power MW_e	Produced El. Power MWh	Type
KKN Niederaichbach	1972	1974	321	0.01	CO_2/D_2O
KRB A Gundremmingen	1966	1977	237	15 000	BWR
KWL Lingen	1968	1977	256	11 000	BWR
MZFR Karlsruhe	1966	1984	50	5 000	PWR
VAK Kahl	1962	1985	15	2 100	BWR
AVR Jlich	1968	1988	13	1 670	HTR
THTR 300 Hamm-Uentrop	1987	1989	296	2 850	HTR
Rheinsberg	1966	1991	63	?	PWR
Greifswald 1,2,3,4 und 5	1974-1989	1991	408	?	PWR

TABLE II

Uranium Mining and Milling Installations to be Decommissioned (2)

	Area(ha)
1. Uranium mines	
Ronneburg	1030
Drosen	316
Königstein	119
Gittersee	26
Aue	294
Zobes/Mechelgrün	930
2. Milling Installations	
Seelingstädt	964
Crossen	251
Gittersee	30
Lengenfeld	7
3. Tailing basins	
Seelingstädt	370
Crossen	200
4. Numerous conical waste piles and other areas affected by the handling and transport of uranium ore and concentrate.	

dose regardless of its origin, is likely to be regarded as trivial if it is of the order of some tens of μSv per year. It is noted that this level of dose corresponds to a few percent of the annual dose limit for members of the public recommended by ICRP. These principles are applied also to aluminum and copper scrap from NPP's as well as to scrap and apparatuses from uranium mining installations.

For other remains of the uranium mining and milling especially for the release of areas, buildings and rubble some what different principles have been developed. In the already mentioned areas, installations and buildings only naturally occurring radionuclides are present and these radionuclides are present in the environment of these areas at an elevated level compared to other regions of Germany. Consequently the doses to which people are exposed in these areas is mostly already somewhat higher. It is not caused by uranium mining and milling but by nature. In addition the described circumstances caused by uranium mining and milling are preexisting and one can only afterwards try to minimize the consequences for the people (5). Therefore it is required that the additional dose which people will receive as a result of the former activities must not exceed a level which is given by the variation of the natural radiation exposure. Therefore the established exemption limits were orientated at a radiation exposure of 1 mSv/a. Otherwise it could happen that nature would be redeveloped.

RADIATION PROTECTION PRINCIPLES FOR THE SAFE RECYCLING AND REUSE OF LOW LEVEL RADIOACTIVE STEEL AND IRON FROM NPP'S (3)

If recycling in the nuclear field as explained above is not possible or practicable the following three possibilities of release are distinguished:

- Unrestricted release: Completely unrestricted release is possible if the specific overall activity is not higher than 0.1 Bq/g and the surface contamination does not exceed 0.5 Bq/cm^2 for ß-γ-emitters . Each individual item has to comply with these limits. The surface contamination may be averaged over 100 cm^2. It is supposed that no α-contamination is detectable.
- Release for general melting: The release of scrap material for general melting in a normal steel furnace together with other inactive scrap is possible if the specific overall activity of each individual item is not higher than 1 Bq/g, and at the same time, the surface activity conditions for unrestricted release are complied with ($\leq$ 0.5 Bq/cm^2) . The producer of the scrap just has to prove that the scrap material he is going to release is really going into a furnace. The owner of the furnace does not need any license for handling this material.

- Controlled recycling: If the specific overall activity of 1 Bq/g is exceeded, or if it is not possible to measure it because the scrap items are of a too complicated geometrical shape or are too small, a controlled melting is possible - under a special license according to the Radiation Protection Ordinance. The only condition is that, if the product material is going to be released unrestrictedly, the specific activity must not exceed 0.1 Bq/g. In any case the resulting specific activity of the material must not exceed 1 Bq/g. The competent authority can allow this material to be used outside controlled areas if it can be guaranteed that no enhanced exposure to individuals is to be expected.

For all three kinds of release a license by the competent authority is required for each case. For other metal scrap as aluminum and copper similar recommendations are in preparation. In all these cases α-contamination is excluded. For materials with measurable α-contamination stemming from nuclear power plants and installations of the nuclear fuel cycle recommendations for release of materials are still in preparation too. How the above exemption limits are deduced from the general principles mentioned above is described in the paper of Deckert, Graf and Görtz from Brenk Systemplanung presented at this conference too (6).

RADIATION PROTECTION PRINCIPLES FOR THE RELEASE OF SCRAP FROM INSTALLATIONS OF URANIUM MINING AND MILLING

These materials are contaminated at the surface only and as a guiding value one can take 0.5 Bq/cm^2 from annex IX of the German Radiation Protection Ordinance, which is given for naturally occurring uranium. It has been proven that this value is applicable for the release of big amounts of materials. It is estimated that at Crossen a former uranium milling plant about 20000 Mg of steel scrap only is to be disposed off. The main exposure pathway in the course of handling this scrap arises during the cutting of the material and afterwards by the use of the slag remaining after melting. Therefore the following principles have to be followed according to a recommendation of the SSK (German Radiation Protection Commission) (7):

The exemption limit of 0.5 Bq/cm^2 can be applied if the scrap is directly delivered to a scrapdealer and it can be supposed that the material is to be molten. Further there must be no parts or items within the material which might be reused, that means that all those parts must have been destroyed before in order to make them unusable for ever. Finally all parts of the material must have dimensions which allow to put them directly into a melting oven. That means that bigger parts have to be cut before under circumstances where the engaged workers are under radiation protection supervision. It must be secured that the measured surface activity is below 0.5 Bq/cm^2 and representative for all the material. But it is not necessary that all the materials has been measured completely. By knowing the origin and former use of the material corresponding conclusions can be drawn.

RADIATION PROTECTION PRINCIPLES FOR THE RELEASE OF APPARATUSES AND INSTALLATIONS FROM URANIUM MINING AND MILLING INSTALLATIONS (8)

It has been shown that for these materials, if they are contaminated by uranium ore or waste rock only an exemption limit of 0.05 Bq/cm^2 must be applied in order to limit resulting exposure to some 10 μSv. But because a contamination of 0.05 Bq/cm^2 by uranium ore or waste rock would be visible because of the low specific activity of this material a normal cleaning procedure can be applied after which no contamination should be still visible. Only critical spots have to be controlled by measurements.

RADIATION PROTECTION PRINCIPLES FOR THE RELEASE OF BUILDINGS, AREAS AND RUBBLE FROM URANIUM MINING AND MILLING AREAS (9,10)

As mentioned already above in these cases somewhat different radiation protection principles are applied. Therefore the additional radiation exposure which might be tolerated has been limited to 1 mSv/a. It is distinguished between the use of areas and buildings for industrial purposes and other uses. About the use of buildings for non industrial uses a decision about release limits has not yet been taken. The consideration of possible exposure pathways leads to the conclusion that the main pathway is the external radiation e. g. the γ-dose rate above the contaminated area and the probable contamination of ground water. If the possibility of flats, play grounds and kindergartens and similar things on the area of industrial complexes is taken into account the exposure pathway of direct ingestion of soil and dust by playing children can not be excluded. The following criteria are recommended:

- If the specific activity is below 0.2 Bq/g of soil unrestricted release of the area is possible. The U-238 decay series is taken into account to be in radioactive equilibrium. The nominal activity is given by the most influencing radionuclide of the decay chain.
- If the specific activity is below 1 Bq/g the area can be released for industrial purposes under the following conditions:
  - Building and use of company owned flats, play grounds and kindergartens are allowed in only those parts of the whole area where the specific activity is below 0.2 Bq/g.
  - In all other areas the soil has to be covered by inactive soil in order to limit the dose rate to 0.3 μSv/h.

In addition the competent authority has to check before giving the license to release such areas, whether the longterm use of groundwater for drinking purposes which has its origin in these areas will not lead to higher ingestion doses than 0.5 mSv/a. Further it must be secured by suitable measures that new building to be erected on released areas will not contain resulting Rn concentrations of more than 250 Bq/m^3.

The release of buildings for industrial purposes is possible if:

- possible contaminations are caused by uranium ore or waste rock material only,

- the ceilings, walls and floors have been cleaned as far as a contamination is not visible anymore,
- the dose rate in no room exceeds 0.3 μSv/h and,
- it is secured that in case of demolishing the building later on the rubble is dealt with as required beneath.

For the release of rubble the following conditions have to be met:

- If the specific activity is below 0.2 Bq/g an unrestricted release is possible.
- If the specific activity lies between 0.2 and 1 Bq/g the material shall be preferably disposed off on already contaminated areas which are not foreseen for an unrestricted release. It is supposed that such materials are not to be reused and that this landfill will be recultivated after closure.
- If the rubble has a specific activity larger than 1 Bq/g the method of disposal has to be proved in each case according to radiation protection principles.

RADIATION PROTECTION PRINCIPLES FOR THE USE OF AREAS CONTAMINATED BY URANIUM MINING FOR FOREST, AGRICULTURE, PARKS AND LIVING AREAS (11)

The essential figure for the radiation exposure on contaminated areas is the specific activity of uranium 238 decay products of the contaminated soil, where radioactive equilibrium is supposed. For the determination of the specific activity averaging over 100 m^2 is allowed for the depths of

0 - 0.1 m,

0.1 - 0.5 m and from

0.5 m onwards in steps of 1 m down to the zones which are not affected by mining.

The following possibilities are distinguished :

- If the specific activity is below 0.2 Bq/g the area can be used without any restraints.
- If the specific activity lies between 0.2 and 1 Bq/g the area can be used for forest or pasture and grass land without any restraints. For parks it can be used if the soil is covered in order to restrict the dose rate to 0.3 μSv/h. If there are sporting areas or play grounds to be planned the specific activity must be lower than 0.2 Bq/g. The groundwater contamination is to be limited in so far that the resulting radiation dose by ingestion of drinking water should not exceed 0.5 mSv/a.
- If the specific activity is higher than 1 Bq/g special precautions for radiation protection have to be taken.
- All new buildings on released areas should be constructed in order to limit the radon concentration under 250 Bq/m^3.

ACTIVITY RELEASE LIMITS FOR THE UNCONTROLLED DISPOSAL OF VERY LOW LEVEL RADIOACTIVE WASTE BY INCINERATION AND LANDFILL

Since 1979, the Authorities used the following criteria for the release of very low level radioactive waste as if it were nonradioactive (12):

According to the German Radiation Protection Ordinance (RPO) § 47, every licensee is obliged to deliver radioactive wastes to a radioactive waste collection center. § 2 (2) of the Atomic Act requires that only those radioactive wastes are to be considered as nonradioactive for which, because of their low level radioactivity, no special precautions need to be administered in order to protect life and health as well as property against the effects of ionizing radiation. In order to apply these regulations it is necessary to establish activity release limits below which very low level radioactive waste is to be considered as nonradioactive. This is done by defining a de minimis dose which might be received by members of the public but can be considered as negligible because the risk to health which it represents does not warrant the expenditure of the time and effort which would be involved in the regulatory process and is comparable to other risks taken by the general population without any benefit. Similar to the case of the recycling of low level radioactive material, the dose of the order of 10 μSv/a is accepted as de minimis on an international level, which means it can be considered negligible (4).

One criterion that this condition is met is given by § 4 (4) sentence 1 No. 2 e of the RPO which requires for the specific activity that it must not exceed the level of 10^{-4} times the activity exemption limits per gram for the radionuclides concerned. In addition the authority has to take into account the kind, mass and frequency with which the wastes arise before licensing the disposal as conventional waste.

In order to check whether this practice can be applied also in the future, a generic environmental study was performed to calculate which specific activity wastes may have in order to be disposed off as conventional nonradioactive waste leading to an annual dose of not more than 10 μSv/a for members of the general public (13,14). This was done separately for a great variety of radionuclides. The two main pathways of the wastes to be considered were the disposal onto a landfill and delivery to a municipal incineration plant. The most restricting values were calculated for the landfill with the smallest annual waste throughput, because in this case the dilution factor is also small.

In Table III some typical radionuclides are listed together with the calculated specific activity leading to an exposure of 10 μSv/a. For comparison the values used until now in the Federal Republic of Germany are listed under the heading § 4 (4), No. 2 e of the Radiation Protection Ordinance.

It can be concluded that the current practice in the Federal Republic of Germany for most of the radionuclides is conservative. Only in some cases the new calculation resulted in lower values. Consequently the present practice was until now essentially confirmed by the Radiation Protection Commission. But final conclusions are still to be drawn.

CONCLUSION

Table IV summarizes all recommendations for exemption limits given until now. All figures for limits of surface contamination are in agreement with the German Radiation Protection Ordinance Annex IV (RPO). But before using them they were justified by calculation using the relevant exposure pathways. The limits for the specific activity are not given in the RPO. They were calculated by investigation of critical pathways too. In most cases the external radiation exposure

TABLE III

Calculated Figures for Activity Release Limits for the Disposal of Very Low Level Radioactive Waste as Conventional Waste Compared with Presently Applied Figures

Radionuclide	Specific Activity Bq/g	Presently applied (§4 (4), No. 2e)[1)] Bq/g
H 3	2200	500
C 14	570	50
S 35	240	50
Co 60	1.4	5
Sr 90	2.1	5
Tc 99	0.025	500
I 129	0.016	50
Cs 137	6.2	50
Ra 226	1.0	0.5
Th 232	0.1	5
U 238	1.4	500
Pu 239	0.31	0.5

[1] Radiation Protection Ordinance

contributes the most to the total dose. In special cases inhalation or ingestion plays a bigger role.

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TABLE IV

Exemption Limits for the Release of Low Level Radioactive Scrap, Materials, Instruments, Installations, Buildings, Areas and Waste

Conditions	Scrap		Instruments, Installations	Rubble	Areas UMM[3)]			Buildings UMM	Waste, General
	NPP's	UMM	UMM	UMM	Industrial Use	Pasture, Forest	General Use	Industrial Use	From all Sources
Without any restraints	≤0.1 Bq/g ≤0.5 Bq/cm^2 no α-activity	---	---	≤0.2 Bq/g[4)]	≤0.2 Bq/g[4)]	≤0.2 Bq/g[4)]	≤ 0.2 Bq/g	---	0.5 - 500 Bq/g[8)]
With additional restraints	≤1 Bq/g ≤0.5 Bq/cm^2 no α-activity[1)]	≤0.5 Bq/cm^2 total α-activity[1,2)]	0.05 Bq/cm2 total α-activity[3)]	≤ 1 Bq/g[4,5)]	≤1 Bq/g ≤0.3 μSv/h[4,6,7)]	≤ 1 Bq/g ≤ 0.3 μSv/h[4,6,7)]	---	Con-tamination not visible ≤0.3 μSv/h[3)]	---

NPP : Nuclear power plant; UMM : Uranium mining and milling installation

1) It must be secured that all material will be molten down.

2) No directly usable parts allowed among the scrap and for melting necessary cuttings must be made before release under radiation protection conditions.

3) Contamination by uranium ore and uranium waste rock only. No tailings from ore processing.

4) The specific activity is given by that of the most relevant radionuclide of the U-238 decay chain (e. g. Ra-226).

5) Landfills for this rubble should preferably placed on already contaminated areas which are not forseen for any other use in future.

6) 0.3 μSv/h dose rate above the ground should be achieved by covering the soil with inactive material.

7) If severeal areas are released which are drained to a drinking water source it has to be secured that the ingestion dose received by this drinking water should be limited to 0.5 mSv/a.

8) Depending on the radiotoxicity.