ASPECTS OF CLEARANCE AND EXEMPTION OF NORM IN THE NEW GERMAN RADIATION PROTECTION ORDINANCE

S. Thierfeldt, R. Barthel, E. Kugeler
Brenk Systemplanung GmbH, Aachen/Germany
M. Helming, H.-H. Landfermann
Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, Bonn/Germany
(German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety)

1 ABSTRACT

The new German Radiation Protection Ordinance (RPO) contains for the first time a systematic framework of regulations protecting workers and the public against radiation exposures from material with enhanced levels of naturally occurring radionuclides (NORM). This part of the RPO transforms the requirements of Title VII of the European Council Directive 96/29/EURATOM (Basic Safety Standards, BSS). The new German RPO has entered into force on August 1, 2001.

The overall goal of the new regulations is to keep the additional effective dose for the population from the recycling or disposal of NORM below 1 mSv/a. In order to achieve this goal, exemption/clearance levels have been derived generically for various material types, material quantities and disposal/recycling conditions which are laid down in the new RPO. If the material in question satisfies these exemption/clearance levels no further investigation is necessary and the material can be used or disposed of as intended. If the exemption/clearance levels are exceeded a case-by-case analysis would be required which detailedly and case specifically relates the activity contents of the material in question to the resulting dose. If this case-by-case analysis shows that the dose criterion would be exceeded, the work activity in question needs to be licensed.

The first step in deriving specific exemption/clearance criteria for NORM was to analyse the inventory of mass streams and activity concentrations within different industrial branches (including mining) working with NORM in Germany. In a second step, technical processes and options for the recycling and disposal of these materials which are applied in practice were investigated in order to make the radiological exposure scenarios as realistic as possible. On this basis, generic scenarios for the dose calculations concerning the workforce and the public were defined and doses were estimated. All relevant pathways including Radon and possible long term effects (ground water) were considered in these analyses. Based on the 1 mSv/a criterion, a catalogue of relevant materials, potentially requiring radiation protection measures, was developed.

This paper gives an overview of the German regulations on NORM and provides some details on the way the exemption/clearance levels have been derived. It also lists the industries and material types which are primarily concerned by these regulations and outlines how case-by-case investigations could be performed.

In a second part this paper shortly discusses how these German regulations compare to the new recommendations on NORM which are currently being developed by the EURATOM Ar-

ticle 31 Group on “Concepts of Exemption and Clearance”. These recommendations are being based on a different dose criterion (300 µSv/a) and on different radiological scenarios and follow different approaches concerning inclusion of doses from Radon and water pathways. This paper discusses the differences in the two approaches for deriving clearance/exemption levels.

2 INTRODUCTION

The former German Radiation Protection Ordinance (1) as of 1989 did not contain detailed regulations concerning NORM. An overall exemption level of 500 Bq/g for the total activity of natural radionuclides was defined. Materials of natural origin below this level could be handled without restrictions. In contrast to this value, the Radiation Protection Ordinance of the German Democratic Republic (GDR) (2) which is still in effect in some parts of the country (e.g. for reclamation of Wismut areas) set an exemption level of 0.2 Bq/g per nuclide of the U-238 decay chain for the deposition of solid residues. These exemption levels were, of couse, used for quite different purposes.

The new Radiation Protection Ordinance (RPO) (2) which has entered into force on August 1, 2001, has transformed Title VII of the EURATOM BSS (4) into detailed national legislation in its Part 3. Part 3 (§§ 93 to 104) of the RPO refers to

- NORM at workplaces (§§ 95 to 96),
- the protection of the public from NORM (§§ 97 to 102),
- cosmic radiation in conjunction with flight crews (§ 103).

Details concerning workplaces where increased radiation exposure by NORM may occur are given in Annex XI of the RPO. Annex XII of the RPO provides details concerning exemption/clearance levels for NORM with regard to the protection of the public. The new German RPO has thus led to a significant harmonization in the area of NORM residues and workplaces where NORM is processed. This approach has been based of the following steps:

1. identification of and data collection on relevant materail streams arising in mining activities and industrial processes;
2. definition of disposal and/or recycling options for various material categories;
3. definition of appropriate radiological scenarios which link the activity contents in these materials to doses for members of the general public or for workers who are in contact with these materials and derivation of exemption/clearance levels for various types of NORM residues and for various recycling or disposal options.

This procedure is shortly outlined in section 0. A more detailed explanation is provided in (10).

The European Commission recently has issued recommendations which also concern exemption/clearance levels for NORM (5) (section **2.2**). In this paper, the two methods of deriving such levels which were used in Germany and by the Article 31 Group “Concepts of Exemption and Clearance” are presented and compared.

2.1 Exemption/Clearance Levels for NORM in Germany.

2.1.1 Material from Industrial and Mining Processes

The first step of the German approach was the identification of all potentially relevant material streams arising in mining activities and industrial processes. All materials were considered which may have a specific activity concentration significantly higher than found in average soils. The threshold level was set to 0.2 Bq/g per nuclide of the U-238 and Th-232 decay chains in equilibrium. This means that materials with lower activity concentrations were disregarded in the survey. Material types which were considered comprise the following:

- Waste rock and other residues such as sludges and sands from coal mining, the extraction and transport of crude oil and natural gas, ore mining and other mining activities;
- Residues from coal fired power plants (fly ash, bottom ash), gypsum from the cleaning of off-gases and sludges from water treatment facilities;
- Residues of the sulphur and phosphate chemistry utilizing raw materials (e.g. phosphogypsum);
- Slags, precipitates and sludges from the production and processing of iron and steel;
- Residues from the processing of non-iron ores;
- Used zircon sands from foundries;
- Sludges from water preparation facilities;
- Residues from zircon containing refractory materials used in high temperature furnaces (iron/steel industry, non-iron metallurgical processes, foundries, glass and ceramics industry, cement production);
- Residues from W-Th welding electrodes and thorium coated incandescent mantles.

For these materials, typical parameters were evaluated, e.g. activity concentrations, chemical and physical form of the material, quantities which arise and are processed at workplaces or are disposed of, material-specific options for recycling or disposal. These materials were categorized into one of the four categories: soil/rock, sand, ash, slag or sludge according to their physical properties. This categorization has then been used in the radiological analysis.

2.1.2 Recycling and Disposal Options in Germany

The materials listed in section *2.1.1* are either recycled or disposed of. The available recycling or disposal options for a certain type of material depend on the properties and quantity of the material and are also determined by econimical and other factors.

The disposal of these materials can take place above ground or underground. For the subsequent radiological analysis, some characterisitics of the landfill are relevant, e.g. the size (area, capacity) and the type (special landfill for one type of residue, municipal landfill, hazardous waste dump). For the recycling of residues, two main options exist: Use as building material in road construction or use as aggregate in the making of concrete or other building materials. For both options a number of material specific parameters which are relevant for the radiological analysis exist. Finally, the utilization of residues in mines for backfill or similar purposes was considered in analogy to the disposal in underground repositories.

2.1.3 Derivation of the Exemption/Clearance Levels

Remark: For the interpretation of the radiological analysis it must be kept in mind that the surveys presented in sections *2.1.1* and *2.1.2* strictly refer to Germany only. In other countries, different material and residue types may be relevant, and additional recycling or disposal options may apply or some may be precluded. Likewise, the radiological evaluation presented here only refers to the German situation making the resulting exemption/clearance levels also country specific.

The derivation of the exemption/clearance levels has been based on a maximum dose of 1 mSv/a for the general public. For this radiological analysis, the four material categories soil/rock, sand, ash, slag, and sludge have been distinguished. The scenarios have been adapted for the six age groups "≤ 1 a", "1 - 2 a","2 - 7 a", "7 - 12 a", "12 - 17 a" and "> 17 a" according to (4). In addition, workers were considered which may come into contact with the materials (e.g. construction or landfill worker) with the same dose criterion as for members of the general public.

- For the recycling of NORM the following exposure scenarios were considered
  - for workers: road construction, use as aggregate for building materials, storage in a warehouse, use for sand-blasting
  - for other members of the general public: living near a road constructed using NORM, living near a public place covered with NORM, living in a house which has been constructed using NORM.
- For the disposal of NORM three exposure scenarios were considered:
  - for workers: disposal on a landfill, disposal in underground mines;
  - for other members of the general public: living near a landfill or a waste rock dump where NORM is being or has been disposed of

For these scenarios the following exposure pathways have been considered

- external radiation,
- inhalation of contaminated dust,
- inhalation of radon/radon daughter nuclides and
- direct ingestion of fine grained radioactive material.

Where appropriate, also the following exposure pathways were considered

- drinking contaminated water (after groundwater migration of contaminants);
- use of this water for irrigation of agricultural products or for watering cattle (after groundwater migration of contaminants);
- contamination of agricultural products through the deposition of dust.

The dose assessments were based on numerous parameters which are adapted to the scenario type, the age group, and the material category. The parameter values were chosen on the conservative side, yet being as realistic as possible. Details are provided in (6). They take into account e.g. the following aspects:

- Material properties: Physical consistency, which may limit the available options for recycling and disposal, nuclide vector (in ashes and filter dusts the radioactive equilibrium may

be massively disturbed in particular with respect to lead and polonium), particle size distribution, radon emanation and diffusion coefficients, and leachability of contaminants

- Parameters of recycling or disposal options: mixing ratios of NORM in the production of building materials or in the disposal with other materials in landfills and the geometry of objects containing NORM (area and height of landfills, size of living rooms in houses)
- Parameters determining contaminant migration over air and water pathways: meteorological conditions, air exchange rates in buildings, infiltration rate of precipitation into a landfill, and distance and hydrological properties of aquifers and surface waters
- Exposure parameters: exposure times, breathing rates, ingestion rates for food and for direct ingestion of contaminated material, and dose coefficients for the incorporation of radionuclides

2.1.4 Exemption/Clearance Levels

Annex XII of the new German Radiation Protection Ordinance (2) contains a list of types of NORM residues which have to be considered, together with the rather detailed framework for exemption/clearance levels for NORM. Based on the assessments described section *2.1.3*, it was possible to narrow down the list of relevant residues to the following materials:

1. Sludges and scales from the extraction of oil and natural gas;
2. Non-refined phosphogypsum, sludges from its processing and precipitates and slags from the processing of phosphate ores (phosphorite);
3. Waste rock, sludges, sands, slags and precipitates from the extraction and processing of bauxite, columbite, pyrochlore, euxenite, copper shales, tin ores, rare metal and uranium ores, concentrates and residues from the processing of these ores and minerals as well as minerals corresponding to the listed ores arising during the extraction or processing of other raw materials;
4. Precipitates and sludges from the waste gas treatment in primary processes of the iron and non-iron metallurgy.

For the exemption/clearance levels presented in Annex XII of the German Radiation Protection Ordinance (2), a tiered approach is chosen. That means that multiple values are provided which depend on material type and disposal or recycling option. The criteria are expressed in the following form

$$C_{U238max} + C_{Th232max} \leq C \qquad [1]$$

where $C_{U238max}$ and $C_{Th232max}$ stand for the highest specific activities of the nuclides in the U-238 and Th-232 decay chains.

1. The primary exemption level for the recycling or disposal of NORM corresponds to an activity concentration **C=1 Bq/g** in equation [1].
2. An exemption/clearance level of **C = 0.5 Bq/g** in equation [1] is applied in cases where more than 5000 Mg/a of residues are disposed of in the vicinity of a usable aquifer, when building materials for the construction of houses contain more than 20 % residues or when building materials for other purposes (road construction, construction of dams etc.) contain more than 50 % residues.
3. For the recycling or disposal of residues in underground mines a higher exemption level of **C = 5 Bq/g** has been defined.

4. For waste rock resulting from mining activities, a lower clearance/exemption level has to be applied if the recycling or disposal of the material leads to the covering of an area of more than 1 ha in the vicinity of a usable aquifer. In this case, the following exemption/clearance levels apply: $C_{U238max} \leq$ **0,2 Bq/g** and $C_{Th232max} \leq$ **0,2 Bq/g**.
5. A number of further criteria exist which cannot be discussed here. For more details see (6) and (10).

The dose assessment yielded generic exemption/clearance values for which, of course, some uncertainties cannot be avoided. Therefore, if the derived exemption/clearance values are exceed in a particular case this does not automatically mean that a licence will be required. Instead, in those cases a specific assessment might be required which would investigate in more detail whether a dose of 1 mSv/a would really be exceeded.

2. 2 Exemption/Clearance Levels as Recommended by the EURATOM Art. 31 Group

The EURATOM Art. 31 Group on "Concepts of Exemption and Clearance" has recently recommended exemption/clearance levels for NORM (5) (document still in draft status). The levels are shown in

Table 1 . Values exist for the decay chains U^{238}sec, U^{235}sec and Th^{232}sec as well as for K^{40} as well as for relevant single nuclides (like Th^{230}) or sub-chains (like $Ra^{226+,}$ $U^{238+).}$ The column "All materials" lists values which can be applied to the four material categories soil/rock, sand, ash, and slag for recycling and disposal under any circumstances (see discussion below). The column "Wet sludges from oil and gas industry" applies to sludges from pipes, containers etc. which have been contaminated as a result of the application in the oil and gas industry. As this is a very particular case these values will be disregarded in the following.

Table 1: Rounded Exemption/Clearance Levels for NORM as recommended by the EURATOM Art. 31 Group

Nuclides	this includes	All materials (Bq/g)	Wet sludges from oil and gas industry (Bq/g)
U-235sec	entire decay chain	**1**	**10**
U-235+	U-235, Th-231	5	50
Pa-231		5	50
Ac-227+	Ac-227, Fr-223	1	10
U-238sec	entire decay chain	**0.5**	**5**
U-238+	U-238, Th-234, Pa-234, Pa-234m	5	10
Th-230		10	100
Ra-226+	Ra-226, Rn-222 down to Po-214	0.5	5
Pb-210+	Pb-210, Bi-210	5	100
Po-210		5	100
Th-232sec	entire decay chain	**0.5**	**5**
Th-232		5	100
Ra-228+	Ra-228, Ac-228	1	10
Th-228+	Th-228, Ra-224 down to Po-212	0.5	5
K-40		**5**	**100**

The derivation of the exemption/clearance values for NORM according to (5) have been described in another paper of this conference (7) and shall therefore not be presented here in detail. The full derivation procedure is described in the Annex to document (5). The following points, however, need to be highlighted:

- the scope of the radiological assessment is set to workers and members of the general public coming into contact with NORM (no specific workplace scenarios for occupationally exposed workers);
- the exemption/clearance levels are based on the radiological assessment of relevant exposure pathways for NORM encompassing external irradiation, inhalation of dust, and direct ingestion of material;
- the calculations are based on a dose criterion for members of the general public and for workers of 0.3 mSv/a;
- the scenarios take into account common recycling and disposal options for industrial NORM residues like transport, disposal on a heap or landfill, storage, recycling for road construction and in the building industry, living in a house etc.;
- distinction is made between the following material types: waste rock, ash, sand, slag, sludge from the oil/gas industry;
- the scenarios do not apply to the discharge of radioactive substances with air or water, nor to intervention cases and the remediation of former mining sites;

- a background dose reduction is applied (i.e. only the net dose caused by the application of the NORM materials is counted);
- the following rounding procedure for the exemption/clearance levels is used: 1...2.236 → 1; 2.236...7.071 → 5; 7.071...10 → 10;
- a summation rule applies when more than one radionuclides or nuclide chains are present.

There are, however, two important points:

- Inhalation of radon: depending on the exposure situation, the Radon concentration in air (Bq/m³) is calculated and is compared to the level of 200 Bq/m³ (8) for members of the public and 500 Bq/m³ (9) for workers, respectively, while the resulting dose from Radon inhalation is not included.
- Groundwater pathway: spread of radionuclides via seepage from e.g. a heap or a landfill to a groundwater layer and from there to a private well is taken into account by assuming that the groundwater is used for irrigation of plants only. Doses from ingestion of drinking water via a groundwater pathway is not included.

2.3 Comparison of the Two Approaches

The comparison of the two approaches of Germany (developed 1999/2000) presented in section **2.1** and of the EURATOM Art. 31 Group (developed 2000/2001) presented in section **2.2** yields quite interesting observations:

1. The dose criterion for the German levels has been 1 mSv/a while the EU recommendation used 0.3 mSv/a.
2. The German calculations take into account also the doses from Radon inhalation. The EU recommendation only calculates the expected Rn concentration in air and compares it with exemption levels for Radon. However, it does not count the dose from Rn inhalation for the total dose.
3. Concerning groundwater pathways (where appropriate), the German calculations take into account ingestion of drinking water as well as use of this water for irrigation and watering cattle while the EU recommendation only counts doses from irrigation.
4. The German approach provides a set of different exemption/clearance values which depend on the material and the pathway in question while the EU recommendation only gives one single set of values.

These points shall be discussed in more detail:

Observation 1: The allocation of the entire dose criterion of 1 mSv/a in the German approach is based on the premise that 1 mSv/a is to be understood as an acceptable additional dose. At the same time, however, it must be ensured that a scenario where 1 mSv/a is linked to a specific exemption/clearance level is really enveloping. Therefore, the German scenarios are designed in such a way that all contributions to the overall exposure from NORM are encompassed, in particular doses from Radon and drinking water ingestion (see observations 2 and 3). The EU approach on the other hand starts from 0.3 mSv/a. It leaves room for other exposure besides NORM and therefore does not need to be as restrictive in the single scenarios.

Observation 2: The German approach starts from the premise that there is no reason to exclude exposure pathways which will inevitably result from inclusion in the calculation of the total dose. Inhalation of Radon and its progeny contributes to storage scenarios, scenarios

describing living in a house where NORM has been used for construction and living in a house near a heap or landfill. The EU approach relates the Radon concentration to exemption levels for Radon and tests whether those exemption levels might be exceeded in particular cases. Together with the argument given for observation 1, this is also a viable approach.

Observation 3: The EU document (5) relates ingestion of drinking water to the EU directive on drinking water (11) where the dose from this pathway is limited to 0.1 mSv/a. Exceptions are permitted for individual wells of low capacity for which the national authorities could take appropriate measures. The use of water from such private wells as drinking water which has been contaminated via a groundwater pathway can be a very important contribution to the total dose especially for rock type material in cases where large areas are covered and persons live near these areas. Those private wells are still in use in some rural areas. The German therefore included the possible doses from this pathway in order to create exemption/clearance levels that would be applicable in all circumstances.

Observation 4: The tiered approach used in Germany is the result of the concept to create a regulation which is generic in type yet differentiates a number of options (like possibilities for disposal and recycling, material quantities etc.). It must be noted, however, that these options and the corresponding scenario parameters are country specific. A comparable approach would therefore not have been viable on the EU scale. Instead it was regarded as reasonable to define only one set of “unconditional” generic exemption/clearance levels for NORM.

Finally, the numeric values themselves shall be compared. The general value in the German RPO (2) is 1 Bq/g. For some options (like disposal of large quantities in the vicinity of a groundwater layer) a lower value of 0.5 Bq/g applies, for a few other cases (e.g. underground disposal) the value is higher (cf. section *2.1.4*). The value of the EU recommendation (5) which corresponds to the general exemption/clearance value in Germany has been set to 0.5 Bq/g (section **2.2**) and is therefore in quite good agreement. In general both approaches discussed here yield quite similar results despite some procedural differences. It can therefore be concluded that also for NORM the German RPO is in good accordance with EU recommendations.

3 REFERENCES

1. Verordnung über den Schutz vor Schäden durch ionisierende Strahlen (Strahlenschutzverordnung - StrlSchV) vom 13. Oktober 1976 (BGBl. I S. 2905; 1977 I S. 184, 269) in der Fassung der Bekanntmachung vom 30. Juni 1989 (BGBl. I S. 1321, 1926)

2. Verordnung über die Gewährleistung von Atomsicherheit und Strahlenschutz (VOAS); GBl. der DDR, Teil I, Nr. 30, S. 341, 21.11.1984

3. Verordnung über den Schutz vor Schäden durch ionisierende Strahlen (Strahlenschutzverordnung - StrlSchV) vom 20. Juli 2001 (BGBl. I S. 1713, 2001, Nr. 38)

4. Council of the European Communities: Council Directive 96/29/EURATOM of 13 May 1996 laying down the basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionizing radiation; Official Journal of the European Communities, L 159, Vol. 30, 29 June 1996

5. European Commission: Practical Use of the Concepts of Clearance and Exemption – Part II Application of the Concepts of Exemption and Clearance to Natural Radiation Sources; Radiation Protection 122; 5th draft as of 29.06.2001, Luxemburg

6. Brenk Systemplanung: Ableitung von Überwachungsgrenzen für Reststoffe mit erhöhten Konzentrationen natürlicher Radioaktivität, Aachen, Mai 1999

7. Timmermans, C.: Derivation of exemption and clearance levels for NORM; NORM III Symposium, Brussels, September 2001

8. European Commission. Commission Recommendation of 21 February 1990 on the protection of the public against indoor exposure to radon, 90/143/Euratom, Luxemburg, 1990

9. European Commission. Recommendations for the implementation of Title VII of the European Basic Safety Standards Directive (BSS) concerning significant increase in exposure due to natural radiation sources, Radiation Protection No. 88, Luxembourg 1997

10. R. Barthel, W. Goldammer, M. Helming: Exemption Levels for the Recycling and Disposal of Residues with Enhanced Levels of Natural Radioactivity (TENORM) in Germany; paper submitted for the ICEM '01 conference, September/October 2001, Bruges/Belgium

11. Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption, Official Journal L 330, 05.12.1998, p. 32-54