Regulatory Aspects of Clearance and Recycling of Metallic Material forming Part of Buildings of Nuclear Facilities in Germany

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Overview

- Metallic materials as parts of buildings
- Problem / Objective
  - how to perform clearance of these metals without removing them from the building structure
- Clearance regulations in Germany
  - clearance of metals (unconditional and for melting)
  - clearance of buildings
  - comparison
- Strategy for successful clearance of metals as parts of buildings
- Conclusions

Material

- Metallic materials as part of buildings of nuclear installations:
  - reinforcement in concrete
  - anchor slabs
  - pipework buried in concrete
  - steel liners in rooms and in water basins
  - anchor rails that are welded to the reinforcement steel
- These materials
  - remain in the building until the clearance process
  - require special considerations during decommissioning

Objective

- Release as much of this material as possible for recycling
  - by melting in conventional foundries or
  - by melting in a controlled recycling plant for reuse in the nuclear field
- Use only one type of clearance procedure
  - no distinction between
    - clearance process for building surfaces and
    - clearance process for metals on these surfaces
  - this approach saves considerable effort
- This approach is limited to contamination on metal
  - activation requires separate consideration

Problem

- Problem:
  - on the one hand these metallic materials cannot/shall not be removed from the buildings prior to their demolition
  - on the other hand they can only be fully characterised when being removed
- Competent authority has to grant clearance of materials
  - that may not be fully characterised by measurements,
  - but for which a significant part of the information required for clearance is inferred
    - from the operational history
    - from conclusions by analogy
    - from other sources

EXAMPLES

Example:
Reinforcement Steel in Concrete

Example:
Steel Liners on Concrete Surfaces

Example:
Pipes embedded in Concrete

Example:
Halfen Rails / Anchor Rails

Anchor rails

- steel profiles that are tightly fixed to the reinforcement steel
- embedded in concrete
- usually flush with the building surface

CLEARANCE REGULATIONS IN GERMANY

Relevant Parts of the German Clearance Regulations (1)

- Clearance in Radiation Protection Ordinance (*Strahlenschutzverordnung*)
  - general requirements: section 29
  - clearance levels (values): Annex III
  - further requirements: Annex IV

- Clearance levels are laid down in large table in Annex III for each clearance option
  - nuclide specific
  - contains CL values for ~300 nuclides

Relevant Parts of the German Clearance Regulations (2)

- Options for unconditional clearance:
  - of materials for reuse, recycling or disposal including building rubble of less than 1000 Mg/a
  - of building rubble and soil of more than 1000 Mg/a
  - of nuclear sites
  - of buildings for reuse or demolition
- Options for clearance for a specific purpose:
  - of solid materials with up to 100 Mg/a and up to 1,000 Mg/a for disposal on landfills
  - of (solid and liquid) materials with up to 100 Mg/a and up to 1,000 Mg/a for disposal by incineration
  - of buildings for demolition
  - of metal scrap for melting

Relevant Parts of the German Clearance Regulations (3)

extract from Annex III Table 1 RPO
Exemption values and clearance levels

Radionuklid	Freigrenze		Freigabe															
				uneingeschränkte Freigabe von					Freigabe von							Halbwertszeit		
	Aktivität in Bq	spezifische Aktivität in Bq/g	Aktivität HRQ/1/100 A_1 in Bq	Oberflächenkontamination in Bq/cm²	festen und flüssigen Stoffen in Bq/g	Bauschutt, Bodenaushub von mehr als 1 000 t/a in Bq/g	Bodenflächen in Bq/g	Gebäuden zur Wieder-, Weiterverwendung in Bq/cm²	festen Stoffen bis zu 100 t/a zur Beseitigung auf Deponien in Bq/g	festen und flüssigen Stoffen bis zu 100 t/a zur Beseitigung in Verbrennungsanl. in Bq/g	festen Stoffen bis zu 1 000 t/a zur Beseitigung auf Deponien in Bq/g	festen und flüssigen Stoffen bis zu 1 000 t/a zur Beseitigung in Verbrennungsanl. in Bq/g	Gebäuden zum Abriss in Bq/cm²	Metallschrott zur Rezyklierung in Bq/g		
1	2	3	3a	4	5	6	7	8	9a	9b	9c	9d	10	10a	11	
Fe-52	1 E+6	1 E+1	3 E+9	1 E+2	1 E+1	7 E-2		1					2 E+3	1 E+1	8,3	h
Fe-55	1 E+6	1 E+4	4 E+11	1 E+2	2 E+2	2 E+2	6	1 E+3	1 E+4	1 E+4	7 E+3	1 E+4	2 E+4	1 E+4	2,7	a
Fe-59	1 E+6	1 E+1	9 E+9	1	1	2 E-1	6 E-2	1	1 E+1	1 E+1	4	4	3 E+1	1 E+1	45,1	d
Fe-60+	1 E+5	1 E+2													1,0 E+5	a
Co-55	1 E+6	1 E+1	5 E+9	1	1 E+1	1 E-1		1					1 E+3	1 E+1	17,5	h
Co-56	1 E+5	1 E+1		1	2 E-1	6 E-2	2 E-2	1	4	5	1	1	6	0,4	78,8	d
Co-57	1 E+6	1 E+2	1 E+11	1 E+1	2 E+1	3	8 E-1	1 E+1	1 E+2	1 E+2	5 E+1	5 E+1	1 E+2	2 E+1	271,3	d
Co-58	1 E+6	1 E+1	1 E+10	1	9 E-1	2 E-1	8 E-2	1	1 E+1	1 E+1	5	5	3 E+1	1	70,8	d
Co-58m	1 E+7	1 E+4	4 E+11	1 E+2	1 E+4	1 E+4		1 E+3					1 E+9	1 E+4	8,9	h
Co-60	1 E+5	1 E+1	4 E+9	1	1 E-1	9 E-2	3 E-2	4 E-1	6	7	2	2	3	0,6	5,3	a
Co-60m	1 E+6	1 E+3		1 E+2	1 E+3	6 E+1		1 E+3					7 E+7	1 E+3	10,5	m
Co-61	1 E+6	1 E+2		1 E+1	1 E+2	4		1 E+1					5 E+5	1 E+2	1,7	h
Co-62m	1 E+5	1 E+1		1	1 E+1	8 E-2		1					7 E+4	1 E+1	14,0	m
Ni-56	1 E+6	1 E+1													6,1	d
Ni-57	1 E+6	1 E+1													3,6 E+1	h
Ni-59	1 E+8	1 E+4		1 E+2	3 E+2 [1)]	3 E+2	8	1 E+3	3 E+3	1 E+4	3 E+2	3 E+3	9 E+4	1 E+4	7,5 E+4	a
Ni-63	1 E+8	1 E+5	4 E+11	1 E+2	3 E+2	3 E+2	3	1 E+3	1 E+4	6 E+4	1 E+3	6 E+3	4 E+4	1 E+4	100,0	a
Ni-65	1 E+6	1 E+1	4 E+9	1 E+1	1 E+1	4 E-1		1 E+1					3 E+4	1 E+1	2,5	h
Ni-66	1 E+7	1 E+4													54,6	h
Cu-60	1 E+5	1 E+1													23,0	m
Cu-61	1 E+6	1 E+1													3,4	h

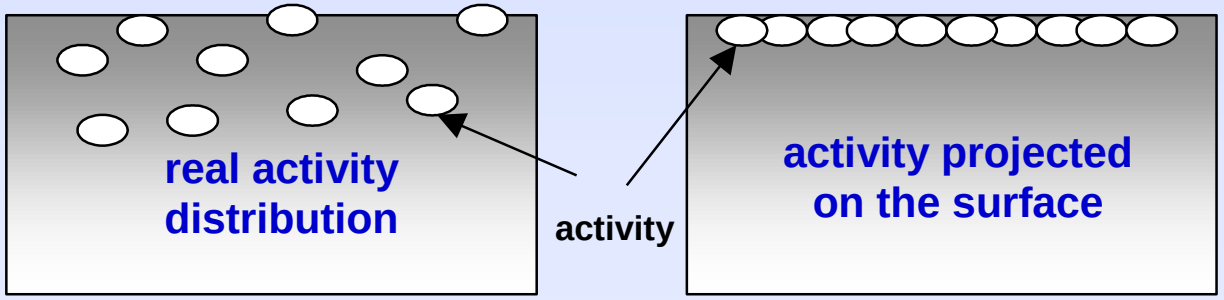
Clearance Regulations in Germany
The Issue with Metals as part of Buildings

- Question:
  - What is the problem of clearing metals as part of buildings?
- Answer:
  - The differences in the CL values and the differences in requirements for clearance of buildings and of metals!

- Question:
  - Why should one try to clear metals in the same way as buildings?
- Answer:
  - Because it is much easier to use just one measurement device and clearance method and to treat the metals as part of the building

Clearance Regulations in Germany Buildings (1)

- Clearance options for buildings:
  - for reuse (or dismantling) – unconditional clearance option
  - for dismantling only – no reuse between clearance measurements and dismantling (standard case for NPP)
- Clearance levels:
  - based on EU RP 113/114
  - higher values for clearance for dismantling only apply
  - expressed as values in Bq/cm²
    - activity penetrated into the volume is projected onto the surface



Clearance Regulations in Germany Buildings (2)

- Averaging area for buildings:
  - 1 m² for buildings for reuse (unconditional option)
  - > 1 m² (often 10 m²) for buildings for demolition

- Measurements
  - usually carried out with (collimated) in situ gamma spectrometry or contamination monitors
  - takes into account penetration depth of contamination into the surface

Clearance Regulations in Germany Metals

- Clearance options for metals:
  - unconditional clearance – reuse, recycling (and disposal)
  - for recycling by melting only – metal must not be reused before recycling
- Clearance levels:
  - unconditional: general CL of Germany
  - for melting: based on EU RP 89/101/117
  - expressed as values in Bq/g (additional surface related values apply for unconditional clearance)
- Averaging criteria:
  - 1,000 cm^2 for surface contamination values
  - several 100 kg for mass related CL

Clearance Regulations in Germany "Buildings vs. Metals"

- How to compare clearance regulations for buildings and metals?
  - different types of CL: Bq/cm² vs. Bq/g
  - different values of CL: the CL for buildings cannot be converted by a standard factor into CL for metals
    - reason: different scenarios
  - different averaging criteria:
    - ~10 m² for buildings vs. 0.1 m² for metals (surface)
    - several 100 kg for metals (bulk)
- Solution:
  - show that application of CL for buildings also for metals in buildings will not lead to violation of 10 µSv/a dose criterion

STRATEGY FOR CLEARANCE OF METALS AS PART OF BUILDINGS

Clearance of Metals as Part of Buildings What can happen to the Metal?

- When metal is cleared together with the building, it will be dismantled together with the buidling structure
- Dismantling will destroy the metal structure and render it unsuitable for direct reuse
  - metal has to be brought to recycling by melting

Clearance of Metals as Part of Buildings Relation of both Sets of CL (1)

- Assumption:
  - contamination on metal surface equals CL for buildings (expressed in Bq/cm²)
- What is the mass related activity of the metal (Bq/g)?
  - depends on thickness! (ρ = 7.8 g/cm³)

	CL for		Activity in [Bq/g] for a thickness of					
Nuclide	buildings, demol. [Bq/cm²]	metals, recycl. [Bq/g]	0.5 cm	0.7 cm	1 cm	1.4 cm	2 cm	3 cm
Co-60	3	0,6	0,77	0.55	0.38	0.27	0.19	0.13
Cs-137+	10	0,6	2.56	1.83	1.28	0.92	0.64	0.43
Sr-90+	30	9	7.69	5.49	3.85	2.75	1.92	1.28

Clearance of Metals as Part of Buildings Relation of both Sets of CL (2)

- Result of comparison:
  - if the nuclide vector is rich in Co-60 and thickness of the metal ≥ 7 mm:

  → even if CL for buildings (3 Bq/cm² for Co-60) is fully exhausted, the CL for metals are complied with

- But what if the metal
  - is thinner than 7 mm or
  - has a nuclide vector rich in Cs-137+?

  → then a more detailed line of argument is required!

Clearance of Metals as Part of Buildings Relation of both Sets of CL (3)

1) What is the total activity on metals remaining in the building of an NPP?
   - assume overall area covered with metal structures in an NPP building to be cleared as around 1,000 m²
   - assume that CL for buildings are fully exhausted and that the nuclide vector is rich in Cs-137+ (unfavourable case)
   - total activity around 70 MBq
   - total mass around 78 Mg (1 cm thickness, ρ = 7.8 g/cm³)

2) Real activity will be much smaller than 70 MBq
   - calibration of the measurement instruments
   - nuclide vector uses conservative activity composition (overestimation of real activity)
   - clearance measurements will never exhaust CL by 100 %

Clearance of Metals as Part of Buildings Relation of both Sets of CL (4)

3) Real activity on metal surfaces will correspond to about 0.4 Bq/g (related to nuclide vector rich in Cs-137+)
   - this is less than the corresponding CL of about 0.6 Bq/g

4) This activity is compatible with the scenarios that have led to the CL for metals for recycling by melting
   - dose criterion 10 µSv/a will be complied with

Clearance of Metals as Part of Buildings
Averaging Criteria for Metals

5) Averaging criteria for metals are also complied with:

- example:
  - averaging area 10 m² on building surfaces
  - thickness of wall cladding 0.5 cm
  - one measurement covers 390 kg of metal
  - compatible with assumptions in RP 89

Thickness [cm]	Area [m²]	Mass [kg]
0.5	10	390
1	10	780
1	5	390
3	5	1,170
5	1	390
10	1	780

- surface related CL play no role for clearance of metal scrap for recycling

Clearance of Metals as Part of Buildings
Metal inside Building Structures

- What about cross contamination (dust) of metallic structures inside building structures during demolition?
- When building rubble is crushed, reinforecement steel is removed
  - possible cross-contamination from residual activity in dust
- Question: Is this a relevant pathway?
- Answer: No! Assume dust layer of 0.01 cm on steel rod of r = 0.5 cm:

$$f = \frac{2\pi\, r\, l\, d\, \rho_{dust}}{\pi r^2\, l\, \rho_{iron}} = \frac{2\pi \cdot 0.5 \cdot 0.01 \cdot 2.3}{\pi \cdot 0.5^2 \cdot 7.8} \approx 1\,\%$$

  - mass related activity of metal will be less than 1 % of residual activity in rubble

CONCLUSIONS

Conclusions

- Clearance of metals as part of buildings
  - significantly simplifies overall clearance procedure
    - no separate procedure for all metallic parts
  - allows continuation of measurements on building surfaces also on metallic objects with same device and same CL
- Radiological evaluation shows that
  - compliance with clearance requirements for buildings (CL, averaging area) will also guarantee compliance
  - with clearance requirements for metal scrap for melting
- Metallic material (scrap) is separated during (conventional) dismantling of the building
  - will automatically be brought to recycling by melting as it is no longer fit for reuse