# Radioactive waste management: Review on clearance levels and acceptance criteria legislation, requirements and standards

Franz-Josef Maringer, J. Šuráň, P. Kovář, Bruno Chauvenet, V. Peyres, E. García-Toraño, L. Cozzella, P. de Felice, B. Vodenik, M. Hult, et al.

# RADIOACTIVE WASTE MANAGEMENT: REVIEW ON CLEARANCE LEVELS AND ACCEPTANCE CRITERIA LEGISLATION, REQUIREMENTS AND STANDARDS[1]

F J Maringer*[a], J Šuráň[b], P Kovář[b], B Chauvenet[c], V Peyres[d], E García-Toraño[d], M L Cozzella[e], P De Felice[e], B Vodenik[f], M Hult[g], U Rosengård[g], M Merimaa[h], L Szücs[i], C Jeffery[k], J C J Dean[k], Z Tymiński[l], D Arnold[m], R Hinca[n], G Mirescu[o]

[a]BEV – Bundesamt für Eich- und Vermessungswesen, Wien (Austria), [b]CMI - Cesky Metrologicky Institut, Brno (Czech Republic),[c]CEA - Commissariat à l'énergie atomique et aux energies alternatives, Gif sur Yvette (France), [d]CIEMAT - Centro de investigaciones energeticas, medioambientales y tecnologicas, Madrid (Spain), [e]ENEA - Agenzia Nazionale per le nuove tecnologie, l'energia e lo sviluppo economico, Roma (Italy), [f]IJS - Institut Jozef Stefan, Ljubljana (Slovenia), [g]EC-JRC-IRMM - European Commission, Joint Research Centre, Institute for Reference materials and Measurements, Geel (European Commission), [h]MIKES - Mittatekniikan Keskus, Espoo (Finland), [i]MKEH - Magyar Kereskedelmi Engedelyezesi Hivatal, Budapest (Hungary), [k]NPL – National Physical Laboratory Management Limited, Teddington (UK), [l]NCNR RC POLATOM - Instytut Energii Atomowej, Otwock-Swierk (Poland), [m]PTB – Physikalisch-Technische Bundesanstalt, Braunschweig (Germany), [n]SMU – Slovenský Metrologický Ústav, Bratislava (Slovakia), [o]TU Wien – Vienna University of Technology (Austria)

** Correspondence to: BEV — Bundesamt für Eich- und Vermessungswesen, Arltgasse35, 1160 Wien, Austria.*
*E-mail addresses: franz-josef.maringer@bev.gv.at, franz-josef.maringer@boku.ac.at*

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**Highlights**

- Legislation, requirements and standards in radioactive waste management
- Strategies and methods to maintain the relevant clearance levels and acceptance criteria
- International, European and national activity levels and limits for exemption and clearance of radioactive waste
- Requirements for acceptance for storage and final disposal of radioactive waste
- Metrological requirements for radioactive waste characterisation

**Keywords:**

Radioactive waste management

Exemption levels

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**Abstract**

In 2011 the joint research project *Metrology for Radioactive Waste Management (MetroRWM)* [1] of the *European Metrology Research Program (EMRP)* started with a total duration of three years. Within this project, new metrological resources for the assessment of radioactive waste, including their calibration with new reference materials traceable to national standards will be developed. This paper gives a review on national, European and international strategies as basis for science-based metrological requirements in clearance and acceptance of radioactive waste.

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## Introduction

After more than fifty years operation of nuclear facilities in medicine, research, military and electric power production in Europe, there is an increasing need in long-term safe and cost-effective radioactive waste management. The radioactive waste management process usually starts with waste characterisation, which together with waste acceptance requirements will decide on the future steps that the waste must undergo until it reaches its final disposal or storage facility. Radioactive waste characterisation includes analysis of radionuclide species and measurement of activity, activity concentration and surface activity. To develop and establish practicable and accurate activity measurement techniques to facilitate state-of-the-art radiation protection requirements and regulations is a very important scientific task in radioactive waste management.

On 29 September 2011, the European Commission – and recently on 25 June 2012 the Council of the European Union – published the proposal for a new Council Directive laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation (EC, 2011; CEU, 2012).The European legislation on radiation protection needs to be updated following the new recommendations in Publication 103 of the International Commission on Radiological Protection (ICRP, 2007) and the experience from the implementation of the current requirements. In this Council Directive proposal it has been declared there is benefit in having the same activity concentration values both for the exemption of practices from regulatory control and for the clearance of materials from regulated practices and it has been concluded that the values recommended in IAEA document RS-G-1.7 (IAEA, 2004) can be used both as default exemption values, replacing the activity concentration values laid down in Annex I to EU Directive 96/29/Euratom (EC, 1996), and as general clearance levels, replacing the values recommended by the European Commission publication Radiation Protection No 122 (EC, 2000). Therefore the future strategy and metrological methodology in radioactive waste management within the Member States of the European Union have to be developed according to this emerging European Council Directive.

In October 2011 the three-years Joint Research Project 'MetroRWM - Metrology for radioactive waste management'[2] started in the frame of the European Metrology Research Programme EMRP. During the project, standardised traceable measurement methods for solid radioactive waste focused on free release or acceptance to repositories, novel instruments and methods for in-situ measurements, gaseous effluent monitors/samplers for stored wastes, and standard sources and reference materials will be developed (EMRP ENV09, 2011). Also, decay data for long-lived radionuclides relevant to radioactive waste processing will be improved.

Clearance levels for radioactive waste and criteria for free release into the environment are defined by guidelines, recommendations and legislative documents for mass and surface activity of individual radionuclides. All medium-active or low-active waste must be characterised by measurements before being stored in repositories and evidence of meeting acceptance criteria must be documented. In repositories, gaseous radioactive emissions must be measured for waste degradation monitoring and radiation protection purposes.

This paper comprises comprehensively the results of Task 1.1 "Review of clearance levels and acceptance criteria legislation, requirements and standards" of the EMRP joint research project Metrology for radioactive waste management (Maringer et al., 2011). The aim of this task was to prepare a review on European and national legislation, national authorities' requirements, international and national standards and recommendations of international agencies for solid radioactive waste processing. The result of this review acts as basis for reasonable metrological target values (e.g. minimum detectable activities, maximum total measurement uncertainties) for relevant radionuclides in future measurement technologies.

Clearance levels and acceptance criteria specifications are under the authority of national regulators. Although several international organisations, like the IAEA – International Atomic Energy Agency

[2] MetroRWM homepage: http://www.radwaste-emrp.eu/

and the EC – European Commission have issued recommendations, the differences are still significant.

## International recommendations on radioactive clearance levels and acceptance criteria

### Exclusion, exemption and clearance

According to the international understanding (e.g. IAEA, 1996), the term “exclusion” refers to the deliberate exclusion of a category of exposure from the range of an authority performing regulatory control based on the fact that it is not considered amenable to control through the regulatory authority in question. Exposure on which the term “exclusion” is applicable is then called excluded exposure.

The concept of exemption is employed only in the context of practices or sources within practices. Basically, exemption may be regarded as a generic authorization issued by the regulatory body, which automatically exonerates the practice or source from requirements such as those relating to notification or authorization. Radionuclides of both natural origin and artificial origin may be submitted to exemption.

Two main exemption criteria are stated based on international commitment:

- the effective dose expected to be inflicted on any member of the public due to an exempted practice or source should not exceed 10 μSv in a year;
- either the collective effective dose caused by one year of activity of the practice is less than approximately 1 Sv or an evaluation performed for the optimization of protection points towards exemption as the optimum solution.

Clearance defines the dismissal of a radioactive material or object within authorized practices from further regulatory control by the regulatory authority. The concept of clearance is tightly connected to the concept of exemption, such that clearance levels must also obey the exemption criteria and must not surmount the exemption levels specified as activity concentration for each radionuclide.

However, materials with activity concentrations lower than the exemption levels may require further consideration from the regulatory body depending on other factors and/or criteria.

Figure 1 illustrates the concepts of exclusion, exemption and clearance, all in relation to the regulatory control.

**Acceptance criteria for processing radioactive waste**

Waste characterisation is an important part of waste management. The first inspection and the assertion of the characteristics of the incoming waste performed by the operator of a pre-disposal facility (e.g. the operator of a conditioning facility) will indicate what conditioning and disposal decisions will be made with regard to the respective waste. At the time of their admittance to their conditioning facilities, the contaminated materials exhibit certain characteristics and it is the task of the conditioner to decide based on these characteristics which waste acceptance criteria, i.e. the WAC of which repository will be most easily and cost effectively reached through the conditioning process.

The purposes of waste acceptance criteria are the safe transportation, handling, storage and disposal of waste packages. Waste acceptance criteria are facility-specific or site-specific and may differ on a package type basis. It is the responsibility of the repository or interim storage operator and of the national authorities or regulatory bodies to establish the appropriate criteria for each interim storage and/or disposal facility.

Important parameters characterising radioactive waste are (IAEA, 1996a):

- Package identifier or number
- Type and version
- Specification (e.g. reference to the waste package specification)
- Name of the conditioning facility and site
- Date of conditioning

- Content of raw waste and details on: waste class, source, description, radiological, physical, chemical and biological properties and the typical waste content (mass) per container (in kg)
- Details about the container: type and variant, manufacturing specification reference
- Details about the immobilizing matrix (if applicable): type and specification
- Details about the capping matrix (if applicable): type and specification
- Activity content: total alpha (in Bq), total beta-gamma (in Bq)
- Dose rate: at the surface and at a distance of 1m (in each case in Gy $h^{-1}$)
- Heat rating (in W)
- Surface contamination: total alpha and total beta-gamma (in each case in Bq $cm^{-2}$)
- Overall package weight (in kg)

**Activity concentration limits for exemption and clearance of radioactive waste**

For the purpose of deriving activity concentration and total activity values for exemption and clearance of radioactive waste, a set of representative exposure scenarios was put together and the values were calculated under the assumption that those values would cause effective doses to designated critical groups for exemption, including the possibility of low probability events.

For radionuclides of artificial origin, the estimation of the values of activity concentration was facilitated by the evaluation of a set of typical exposure scenarios for all material, including exposure from external irradiation, dust inhalation and both direct and indirect ingestion.

Both realistic parameter and low probability parameter values were used and the lower values of activity concentration arising from the application of the corresponding effective dose criteria were used as levels for exemption and clearance.

Realistic parameter values correspond to an effective dose criterion of 10 μSv per year and the low probability parameter values make use of an effective dose criterion of 1 mSv per year and a skin equivalent dose limit of 50 mSv per year.

Annual doses are calculated with the help of dose coefficients, which are compiled in CEU (2012) for the exposure pathways: external exposure, inhalation exposure, ingestion exposure and skin exposure.

The derivation of activity concentration values for material containing radionuclides of artificial origin (except foodstuffs and drinking water) is carried out according to:

- Defining and validation of reasonable conservative scenarios and parameter values
- Calculating annual effective doses relating to the unit specific activity (1 Bq $g^{-1}$) for each radionuclide
- Identifying the limiting scenario, i.e. the one resulting in the highest dose for each set of calculations
- Deriving the radionuclide-specific activity concentration values by using the appropriate reference dose level (10 µSv $y^{-1}$, 1 mSv $y^{-1}$ or 50 mSv $y^{-1}$) and dividing it by the annual dose calculated for the unit specific activity for the limiting scenario
- Applying rounding procedures to the resulting activity concentration values

The calculation and international recognised activity concentration limits for exemption and clearance of radioactive waste is given in IAEA (2005). Examples of these limits for single radionuclides are shown in table 1. The complete list of radionuclides' activity concentration limits are compiled in IAEA (2005) and Maringer et al. (2011).

**National legislation and regulations on radioactive clearance levels and acceptance criteria in Europe**

The individual national regulations and legislations concerning clearance levels and acceptance criteria for radioactive waste in Europe are heterogenic. Also the regulating governmental authorities are differently organised in this issue of nuclear safety. Whereas the principal concepts of all national regulations in Europe are based on the international and European standards, the detailed

specification, characterisation and legislative regulations and technological standards are different in the European Countries.

In this paper only some specific examples of national individualities can be indicated. The complete structure and individual national regulations and standards concerning exemption, clearance and acceptance are summarised in the technical report of the joint research project (Maringer et al., 2011).

In the *Czech Republic* detailed limits and conditions for the safe operation of radioactive waste repositories and conditions of acceptance – specific for the particular repository site Dukovany, Bratrstvi and Richard Litomerice – are established. For example, the limiting conditions of radioactive waste accepted for storage in the Richard Litomerice radioactive waste repository according to Annex 1 of the Czech regulation No. 307/2002 (SÚJB, 2002; based on the Czech Act No 18/1997) is given in table 2.

In conjunction with other specific conditions the ambient equivalent dose rate on the surface of a RAW unit must not exceed 2 mSv $h^{-1}$. In justified cases, upon agreement with the RAW repository administrator, up to 10 mSv $h^{-1}$ may be permitted. Declared surface contamination of an overpack with RAW must not exceed:

- 3 kBq $m^{-2}$ for alpha-emitting radionuclides,
- 30 kBq $m^{-2}$ for beta- and gamma-emitting radionuclides.

*Austria* – as European country without nuclear power plants – is running only one low level and intermediate level radioactive waste repository in Seiberdorf (Nuclear Engineering Seibersdorf GmbH). The conditions and legal requirements for the safety operation of this repository is given in the Austrian Radiation Protection Act (BGBl. I Nr. 13/2006) and the Austrian general Radiation Protection Regulation (BGBl. II 191/2006, ammended recently by BGBl. II Nr. 76/2012).

For clearance of radioactive waste, the average mass at activity concentration measurements may not exceed 300 kg and the averaging area for surface contamination measurements can be up to 1000 $cm^2$.

For clearance of building waste and excavated soil, the averaging mass at activity concentration measurements may be up to 1000 kg. In justified cases, the competent authority may permit higher averaging masses. The average area for surface contamination measurements of buildings can be up to 1 $m^2$.

The general classification scheme for the disposal of radioactive waste in *France* is shown in Figure 2. Specific conditions and acceptance criteria for disposal of RAW are legislatively defined for each waste category and specific waste repositories in France. The current implementation of the nuclear waste management is appointed in the French national plan for the management of radioactive materials and waste (DGEC-ASN, 2009).

Additionally, detailed conditions, regulations and technological standards for exemption and clearance of radioactive waste and acceptance criteria for disposal established in *Spain, Italy, Slovenia, Belgium, Sweden, Finland, Hungary, Poland, Germany, Slovakia and the United Kingdom* are comprehensively compiled in the technical report Maringer et al. (2011). Generally, the legal requirements and regulations in all European Countries are well developed but nationally specific. The prospective amendment of the European Union's Radiation Protection Basic Safety Standard Directive (EC, 2011; CEU, 2012) could stimulate a European homogeneously approach to the radioactive waste management. This stimulated future harmonisation effort of the European Union member states and associated European countries could result in technologically and economically more effective practise in radioactive waste management.

**European guidelines on radioactive clearance levels and acceptance criteria**

The current national regulations and requirements in Europe are based on the Radiation Protection Directive 96/29/EURATOM (EC, 1996). The basic requirements of this Directive for clearance and acceptance of radioactive waste are well implemented in the national legislations and regulations in Europe.

Taking into account the recent revision draft of the European Basic Safety Standards Council Directive for Radiation Protection (CEU, 2012), future requirements in metrological aspects of clearance and acceptance criteria have to be focused on the requirements given in the proposal for a council directive from 25 June 2012. The proposed Directive is expected to be adopted by the European Council and come into effect in 2013 or 2014. This would give time to EU member states until 2015 to 2017 to implement the new requirements and to update current national legislation in radiation protection.

There are some important changes and new developments concerning radioactive waste management included in the Council Directive draft (CEC, 2012: Preamble (21) – (23)):

- It has been concluded that the values recommended in IAEA document RS-G-1.7 (IAEA, 2004) can be used both as default exemption values, replacing the activity concentration values laid down in Annex I to Directive 96/29/Euratom, and as general clearance levels, replacing the values recommended by the Commission in Radiation Protection No 122 (EC, 2000).
- Member States may grant specific exemption from authorisation for certain practices involving activities above the exemption values.
- Specific clearance levels, above the default values for exemption and clearance, as well as corresponding Community guidance remain important tools for the management of large volumes of materials arising from the dismantling of authorised licensed facilities.

This principal guidance gives the EU Member States the licence to lay down individual activity concentration limits for specific radioactive waste management situations. Detailed exemption and clearance criteria are laid down in Annex VI of the Council Directive draft. For each artificial and

natural radionuclide arising in practice, the default activity limits and activity concentration limits for exemption and clearance of solid materials for re-use, recycling, conventional disposal or incineration are given. Higher limits may be defined by the EU Member States for specific situations, materials or specific pathways, taking Community guidance into account, including where appropriate additional requirements in terms of surface activity or monitoring requirements. For mixtures of artificial radionuclides, the weighted sum of nuclide-specific activities or concentrations (for various radionuclides contained in the same matrix) divided by the corresponding exemption value shall be less than unity. Where appropriate this condition can be verified on the basis of best estimates of the composition of the radionuclide mix (CEU, 2012). The general exemption and clearance criteria have been simplified (CEU, 2012: Annex VI):

- The effective dose expected to be incurred by an individual due to the exempted practice with artificial radioactivity is limited to the order of 10 μSv or less in a year.
- For naturally occurring radionuclides the effective dose increment, allowing for the prevailing background radiation from natural radiation sources, liable to be incurred by an individual due to the exempted practice is limited to the order of 300 μSv or less in a year for members of the public and less than 1 mSv in a year for workers. The assessment of doses to members of the public shall take into account not only pathways of exposure through airborne or liquid effluent, but also pathways resulting from the disposal or recycling of solid residues.

**Conclusions**

The main goal for the derivation of limits of activity, activity concentration and surface activity for exclusion, exemption and clearance of radionuclides of both natural and artificial origin in conjunction with radioactive waste management is the protection of the human population and the environment. For individual dose assessment, scientifically based and internationally committed effective dose criteria, upon which the development of these activity limits are based, provide

assurance that no harm can emerge from exposure to radioactive material which was previously cleared from regulatory control using these derived clearance levels.

The overview of the general waste acceptance requirements provided in this paper extracted from the technical report of the EMRP joint research project MetroRWM is meant to deliver current knowledge regarding to adequate measurement methods and techniques which can be used during the conditioning, storage, and disposal stages.

Although there is a simplified and harmonised concept for exemption and clearance of radioactive waste drafted in the current revision of the European Council radiation protection directive, the EU member states are free to establish higher limits for activity concentrations for individual radioactive waste situations in compliance with the basic effective dose requirements.

Metrology plays an important role in the waste management process, ensuring accurate and reliable waste characterisation for safe and cost-effective waste processing, storage and disposal. Necessary laboratory intercomparison exercises, proficiency tests and high quality end user activity measurement methods have to be supported by state-of-the-art radionuclide metrology – provided e.g. by the European joint research project MetroRWM. To check the conformity of activity measurements with legal limits, the target values of minimum detectable activities have to be below 0.1 of the activity limits and the end user total relative measurement uncertainties should be in any case below 10 %. These metrological target values help to establish a reasonable relation of safety and trust between society, waste generators, conditioners, storage and final disposal operators.

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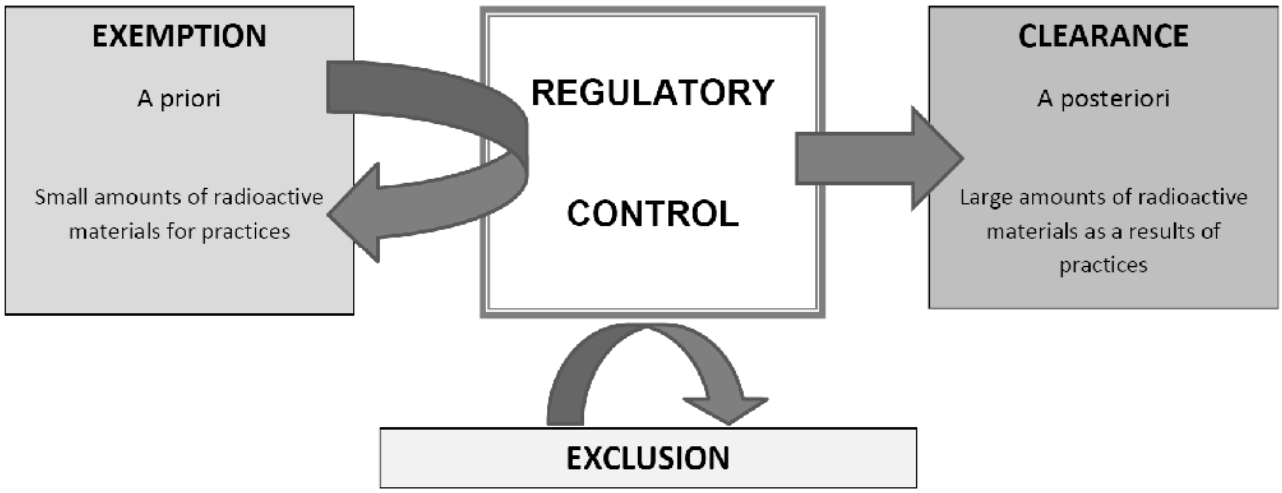


**Figure 1.Relation of exclusion, exemption and clearance to regulatory control (Maringer et al., 2011).**

| | | *Half-life category* | | |
|---|---|---|---|---|
| | | **Very short-lived (< 100 days)** | **Short-lived (< 30 years)** | **Long-lived** |
| ***Waste category*** | **Very low level (VLLW)** | Radioactive decay | VLL surface disposal (or recycling) | |
| | **Low level (LLW)** | | Surface disposal (Aube resporitory) | Sub-surface disposal (currently under investigation) |
| | **Intermediates level (ILW)** | | | Pathway under investigation within the framework of article L. 542 of the Environment Code |
| | **High level (HLW)** | | | |

**Figure 2. French general classification scheme for radioactive waste disposal (Maringer et al., 2011)**

**Table 1.Examples of activity concentration limits of single radionuclides for exemption and clearance of radioactive waste (IAEA, 2005).**

| Radionuclide | $^{40}$K | All other natural radionuclides |
|---|---|---|
| activity concentration limit / Bq g$^{-1}$ | 10 | 1 |

| Radionuclide | $^{3}$H | $^{14}$C | $^{22}$Na | $^{32}$P | $^{54}$Mn | $^{60}$Co | $^{90}$Sr | $^{99m}$Tc | $^{137}$Cs | $^{125}$I | $^{201}$Tl | $^{232}$U | $^{239}$Pu | $^{241}$Am |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| activity concentration limit / Bq g$^{-1}$ | 100 | 1 | 0.1 | 10 | 0.1 | 0.1 | 1 | 100 | 0.1 | 100 | 100 | 0.1 | 0.1 | 0.1 |

**Table 2. Czech Republic limiting conditions – activity and activity concentrations of radionuclides in waste received at the Richard Litomerice repository in standard (200 l or 216 l) overpacks or activity of lump radioactive waste (RAW) (SÚJB, 2002).**

| Radionuclide | The activity of lump RAW / Bq kg$^{-1}$ | Activity of unsolidified waste in a double overpacks and solidified RAW in a simple overpacks /Bq | Activity of solidified waste in a double overpacks/ Bq |
|---|---|---|---|
| $^{3}$H | 3.0E+09 | 2.0E+12 | 1.0E+13 |
| $^{14}$C | 1.0E+07 | 6.0E+09 | 3.0E+10 |
| $^{36}$Cl | 3.0E+06 | 2.0E+08 | 1.0E+09 |
| $^{90}$Sr | 1.0E+08 | 3.0E+11 | 3.0E+11 |
| $^{99}$Tc | 1.0E+05 | 1.0E+08 | 5.0E+08 |
| $^{129}$I | 1.0E+04 | 4.0E+06 | 2.0E+07 |
| $^{137}$Cs | 1.0E+08 | 3.0E+10 | 1.0E+11 |
| long-lived alpha-emitting radionuclides | 3.0E+04 | 2.0E+07 | 1.0E+08 |