# Technical Note
# ERDO-WG - LWC project – Task2
# Minimum set of WACs for near-surface disposal of VLLW-LLW

## INDEX

# 1 FOREWORD

The high-level objective of the ERDO LWC project is sharing information and methodologies for a better characterization of Legacy Waste in view of possible future management activities and acceptance to disposal.

The activities of the project are arranged in the following Tasks:

Task 1: Survey of existing main Legacy Waste streams

Task 2: Minimum set of WACs for near-surface disposal of VLLW-LLW

Task 3: Main properties of ILW packages potentially suitable for geologic disposal

Task 4: Characterization of main Legacy Waste streams

Aim of Task 2 is deriving a common minimum set of WACs to be respected by the legacy VLLW-LLW streams for a near-surface disposal.

The objective will be achieved by:

- Gathering available information about WACs of near-surface disposal facilities
- Establishing a minimum set of WACs for the legacy VLLW-LLW streams
- Analyzing the methodologies for deriving the relevant measures (to be explored and described in Task4)

Available information has been gathered about the main physico-chemical-radiological WACs currently applied to VLLW-LLW for disposal in operating near-surface repositories and preliminary WACs already in place in countries with a planned near-surface repository.

These WACs have been compared and benchmarked for establishing a set of WACs representing the minimum mandatory quality requirements to be complied by the legacy VLLW-LLW streams for disposal.

The methodologies to put in place or to be employed for deriving the relevant measures will be analyzed in the Task 4 of the project.

The present deliverable reports the results of these activities.

## 2 INFORMATION ON WACS RECEIVED WITH A SPECIFIC QUESTIONNAIRE

Questionnaire was arranged and circulated among the interested organizations of different countries to gather information about WAC (generic or specific, definitive or preliminary) for VLLW/LLW near surface repository.

Following a description of the collection data system.

The questionnaire sent had this structure:

| Properties | Acceptance criteria | Safety reason | Qualitative description | Remarks |
| --- | --- | --- | --- | --- |
| 1. Radiological | | | | |
| 2. Chemical | | | | |
| 3. Physical | | | | |
| 4. Mechanical | | | | |
| 5. Thermal | | | | |
| 6. Biological | | | | |
| 7. Package and labelling | | | | |

It was basically divided into seven categories (Radiological, Chemical, Physical, Mechanical, Thermal, Biological, Package and Labelling).

Later in the final summary board and in the comparison chapter cathegories chosen were just 4 (radiological, chemical, mechanical, others/physical).

### 2.1 Addressed countries (operating/planned repository)

Organizations/Countries involved were:

- NES (Austria)
- FUND-NEK (Croatia)
- DD (Denmark)
- NCSRD (Greece)
- SOGIN (Italy)
- COVRA (Netherlands)
- NND (Norway)

- ARAO (Slovenia)
- ENRESA (Spain)

## 2.2 Received replies

Answers to questionnaire were received from Croatia and Spain, therefore, in order to increase the information about WAC, it was obtained from other sources, such as the documentation of some international working groups or other free published documentation.
Although on the one hand, the research carried out has made it possible to increase the information on the WACs available or declared, on the other hand it has highlighted a lack of homogeneity in the information on the WACs adopted by the different countries for their deposits.
This is an aspect to consider in the comparative analysis to be carried out and in the list of minimum WACs required for a radioactive waste repository that we will try to define.
At the end of the search information were collected on 18 Countries.

# 3 INFORMATION ON WACS AVAILABLE FROM OTHER PROJECTS

The international projects, which deal, at least in part, with studying the criteria for accepting radioactive waste at a near surface repository and which have been considered in our analysis, with the aim of obtaining information on WACs, are:

- ROUTES
- PREDIS

Following a description of the information obtained from these projects

## 3.1 ROUTES

- Description of the project
- Exchanges with LWC
- Relevant WACs collected

“Waste management routes in Europe from cradle to grave” (ROUTES) ROUTES is a Strategic Studies Work Package (WP) within EURAD [R2].
The objectives of ROUTES are to:

- Provide an opportunity to share experience and knowledge on waste management routes between interested organizations (from different countries, with programs at different stages of development, and with different amounts and types of radioactive waste to manage).
- Identify safety-relevant issues and their R&D needs associated with the waste management routes (from cradle to grave), including the management routes of legacy and historical waste, considering interdependencies between the routes.
- Describe and compare the different approaches to characterization, treatment and conditioning and to long-term waste management routes, and identify opportunities for collaboration between European Union (EU) Member-States.

Info exchanges with leader of ROUTES, were started by Marja Vuorio in Spring 2020.
Recent publications of interest for ERDO-LWC have been released and can be consulted on the ROUTES’ site.
ERDO-LWC/Sogin attended the ROUTES workshop of 14-15 June 2021 on WAC.
The “Sharing from cradle-to-grave” concept, at the basis of the ERDO-LWC project, has been acknowledged by ROUTES although it was evidenced that sharing predisposal and disposal facilities needs important work of regulatory and WM harmonization.

Both ROUTES and ERDO have many points in common, especially the need for identifying safety relevant issues associated with waste management routes. One of the deliverables of the ROUTES project (Milestone 144: Sharing experience on waste management with/without WAC available - Work Package 9) was used among the source references to determine the relevant WACs.

### 3.2 PREDIS T2.3

- Description of the project
- Exchanges with LWC
- Relevant WACs collected

The overall objective of the Task 2.3 of PREDIS Work Package 2 (WP2) on Strategic Implementation is to provide a critical review of conditioned waste characterization methods, including non-radiological ones, and to compile guidance documents [R1]:

1. For the qualification of conditioned waste forms for disposal. Based on information collected, the expert team will assess information on national approaches, practices, and requirements regarding waste form qualification process and, with regard to this, outline a guide on the bringing evidence that a considered waste form is suitable for disposal.
2. On generic waste acceptance criteria and their derivation based on proven practices. A necessary part of safety measures required while commissioning a disposal facility is the formulation of limits and conditions for its operation. They also include a set of waste acceptance criteria used for the verification of the compliance of waste packages delivered by waste producers to the disposal facility based on safety, technical and administrative requirements. However, even if a disposal infrastructure is missing, waste producers need some instructions for the selection and application of waste conditioning technologies for waste streams to be disposed of in future: these instructions are formulated as generic waste acceptance criteria (G-WAC).

Planned guidance on the formulation of typical G-WAC set which might be applied in national programs not having disposal facilities will draw from collected national analyses and experience of the involved organizations.

The task places a focus on application of this knowledge to small inventory and developing disposal programmes, however, its finding might be considered while updating WAS of more advanced RWM programs as well.

The first year of activities has been devoted to the collection of existing information on waste acceptance systems worldwide (information from 29 national programmes has been collected by Task 2.3 Partners) and – under aegis of the PREDIS coordinator VTT – on establishing links with external subjects.

It is clear that both ERDO and PREDIS 2.3 have many points in common in particular regarding the minimum number of WACs required for a near surface repository. One of the deliverables of the PREDIS project (Deliverable 2.4 - International approaches to establishing a waste acceptance system) was used as a source to extrapolate WACs for some countries included in the table.

### 3.3 Information from other source

Other information was gathered from documents collected from various sources and/or free published documents and at the end of collecting work information were gathered for 18 countries: Belgium, Bulgaria, Romania, Spain, France, Iran, Lithuania, Canada (Ontario), Australia (Sandy Ridge), Germany, Poland, Hungary, Czech Republic, Croatia, United Kingdom, Switzerland, Slovakia, Italy, [R1], [R3], [R4], [R5], [R6], [R7], [R8], [R9], [R10], [R11], [R12], [R13], [R14], [R15], [R16], [R17], [R18], [R19], [R20], [R23].

These countries show different levels of progress in the construction and operation of a radioactive waste repository, consequently there are also differences in the development of WACs for disposal.

At the moment the countries that have operational repositories are: Romania, Spain, France, Poland, Hungary, Slovakia, United Kingdom, Australia, Czech Republic.

Other countries have identified sites and are building or licensing it, these countries are: Belgium, Lithuania and Germany.

The remaining countries have planned the construction of a repository but are still in the siting phase or have yet to decide on a final disposal strategy, these countries are: Italy, Greece, Croatia, Switzerland, Bulgaria and Canada (Ontario).

## 4 COMPARISON OF WACS GATHERED TO DATE

The WACs were grouped into the following four groups

- Common radiological WACs
- Common chemical WACs
- Common physical WACs
- Common biological WACs

**All the collected data on WAC are presented in the annex A**

## 4.1 Common Radiological WACs

Main aspect in a radioactive waste repository is, of course, waste radiological content, both for the safety of the operators/population and for the environment, WACs will focus on limiting the activity concentration values and the total activity, especially for specific radionuclides.
Each country has set limits on the concentration of alpha / beta / gamma activity of the waste to be disposed according to national classification, site safety assessments and accidental scenarios studied by WMOs and validated by safety authorities.
The radiological limits are set based on the type of radionuclide both for waste package and for repository site or just for waste package.
There are also limits for the dose rate at contact and at a distance of 1 m and on the removable contamination; often these limits refer to the regulations for ADR transport (European Agreement concerning the International Carriage of Dangerous Goods by Road) [R22].
Fissile content is limited too for waste package.
Most of the situations analyzed concerned countries that exercise or are building/plaining to build near surface repository, for which limits are also set on the heat production from waste.
Furthermore, according to the repository acceptance criteria, some countries may accept disused radioactive sources, up to certain activity limits, in others they are strictly forbidden.

## 4.2 Common Chemical WACs

Most of the chemical criteria found concern the chemical content of the waste. What is mandatory is the maintenance over time of the stability of the radiological containment barriers and the content limitation of toxic/harmful elements and complexes to avoid risks for the safety of the population and the environment.

Most of the WACs found for the various countries concern the limitation of chemical elements and complexes that can degrade the cement, so there are limitations on the content of chlorides, fluorides, nitrates, sulphates, carbonates.
Explosive, corrosive, oxidizing, easily flammable or flammable, pyrophoric or strongly reactive metallic materials are forbidden.
Also waste that contain or are capable of generating toxic gases, vapors or smoke during transport, handling or storage are not admitted for disposal.
Radioactive waste containing hazardous, biological (organic), pathogenic or infectious agents are forbidden in some countries in others must be treated, conditioned and packed in such a way to minimize hazard.
Some countries do not allow mixing of different materials within the same waste package, in others some categories of materials (organic, powders, fibers and ceramics, oils and paraffins, absorbent materials, soluble etc.) can be inserted in limited quantities or subjected to special treatments before disposal.
For some countries furthermore an inventory of the CMR substances (carcinogenic, mutagen, toxic for reproduction) present in the waste (and later in repository) is needed.
Another concern to consider is that in some way waste content can increase diffusivity of the radionuclides. Therefore, substances forming complex compounds with radionuclides are limited in quantity, because that processes may increase speed of migration of radionuclides into environment. The complexing agent that are limited are substances like EDTA, NTA, DTPA, TTHA, oxalates, citrates, acetates, TBP, ethylene diamine… etc., others like sulfonate and cellulose.
Another way to control radionuclide diffusivity is by controlling matrix leaching parameter, so many countries have range of value for this parameter.

### 4.3 Common Mechanical WACs

WACs in this category refer to the characteristics that the conditioning matrix, the container and the waste form must have to produce a stable package over time, to be considered suitable for disposal.

There are therefore minimum acceptance criteria for the compression resistance of concrete and in some cases also for tensile strength of concrete container.
Metal containers and waste package should withstand external fire, qualification to this criteria is done according to IAEA recommendations for transport. Furthermore, metal container material must be resistant to corrosion.
Wasteforms (the physical form of the waste following treatment / conditioning) must be physically solid and stable, non-reactive and non-flammable, and resistant to degradation. Qualification to criteria of stability for matrix and waste form can be done using some test like radiation resistance, resistance to thermal cycles, resistance to high temperature, biodegradation resistance, stacking resistance, drop resistance and penetration resistance, gas generation, tightness and gas permeability [R21], [R24], [R25], [R26], [R27], [R28], [R29], [R30], [R31], [R32].

### 4.4 Common Other/Physical WACs

All waste packages must be recognizable and easily identifiable therefore a series of characteristics (labels, colors, identification codes) are required to facilitate this task.
There must be no free liquids in the waste packages to avoid a possible increase in the diffusivity of the radionuclides. The values of liquids accepted for waste packages are between 0-3% by volume.
Limits are placed on voids in waste package.

## 5 COMMON WACS TO BE APPLIED TO LEGACY WASTE

- Minimum set of WACs to be applied to Legacy Waste
- Rationale behind the choice

For the purpose of the present project, Legacy Waste is defined as: radioactive waste generated in past activities (energy production, medicine, research, industry) which have been treated and conditioned according to the rules in force at the time or simply stored

pending a suitable management solution; such waste is often lacking sufficient physico-chemical-radiological characterization data for envisaging possible re-treatment/re-conditioning processes in line with current regulatory requirements and/or checking compliance with Waste Acceptance Criteria (WAC) of storage/disposal facilities.
Most countries have not defined waste management strategies for most of them. The common points are:

- the uncertainties about the characteristics of the waste (radiological, chemical physical),
- the classifications
- the treatment processes to be implemented.

What emerged from the analysis of the task 1 results is that in many of the countries involved in ERDO project there are common typologies of waste streams.
Main problem in some countries is the absence of disposal repository, even of a superficial type. This implies the unavailability of definitive WACs, which establish the characteristics to be measured and therefore the measurement techniques to include in the characterization methodology to be identified.
Therefore, it is important to analyze the WACs used in countries with functioning repository to understand how to manage these particular waste streams.
What comes out from the analysis is that many countries have similar WACs, despite differences in production implants, waste and disposal facilities. This is because the main points for long-term safety in the management of radioactive waste repositories are the same.
So first of all there must be a good knowledge of the radiological and chemical content of the waste, even before thinking about any treatment, waste must be adequately characterized and classified. Suitable techniques must therefore be identified to carry out such operations.
As regards the radiological aspect, it is important to identify a list of main radionuclides to be measured and possibly limited in the waste packages.
With regard to the chemical aspect, it is important to identify any substances that are dangerously harmful to the stability of the packages and make sure that it is not present in the waste or adequately treated.

As regards the mechanical aspect, it is necessary to define the minimum quality requirements of the conditioning matrix, the container and the waste package

It is therefore important to develop procedures that enable the radiological and chemical characterization of the waste and the determination of a disposal strategy that allow for the final safe disposal of the legacy waste.

If the waste has already been treated, it is important to carry out an adequate radiological characterization or to identify procedures that make it possible to identify the relevant parameters even indirectly to demonstrate that the waste already treated is in any case acceptable for final disposal.

Following a table that resumes the proposed minim set of WAC/Safety Aspect to be verified in order to perform a Legacy Waste Characterization.

## PARAMETRS AND CHARACTERISTICS TO BE CHARACTERIZED FOR WAC DEFINITION

| Parameter / Characteristic | Description | Limit | | |
|---|---|---|---|---|
| | | Package | Repository Unit | Total Repository |
| **Radiological Characteristics** | | | | |
| **Classification** | The classification must be indicated in order to understand the categories of waste that each country assigns to surface disposal. This helps to understand if there can be a common waste management in different countries | | | |
| **Radionuclide and radiological limits** | Each radionuclide that can be accepted for surface disposal, whose radiological relevance has been derived from any safety analysis, carried out for the disposal plants, must be indicated for single packages (Bq/g), disposal unit (Bq/g) and repository (Bq) | Bq/g | Bq/g | Bq |
| **Fissile e Fissionable Materials** | For single package, Fissile and fissionable elements must be quantified (g) | g | g | |
| **Sources** | For single package, the presence of sources must be indicated, in terms of:<br>- activity associated with each radionuclide;<br>- number of sources. Dimensional category (small, medium, great) should be defined<br>- mix of different sources (different radionuclides) | Bq | Bq | |
| **Dose Rate** | The dose rate resulting from the radiological content of the package must be indicated | mSv/h<br>(Contact, at a 1 m) | | |
| **Surface Contamination** | The surface contamination value must be indicated for each packges | $Bq/cm^2$ | | |
| **Heat** | The heat potentially generated by the radiological content of the package must be indicated | $W/m^3$ | | |
| **Other** | | | | |
| **Chemical Characteristics** | | | | |
| **Organic material** | Organic materials can lead to a degradation of the conditioning matrix and of the manufactured article. The quantity for each packages must be limited | Grams<br>or<br>Volume % | | |
| **Hazardus/Toxic material (Heavy Metals, Volatives, Pesticides)** | Dangerous elements can determine health impacts on the population depending on the total quantity disposed of in the deposit. The quantities for each individual packages must be indicated, in order to be able to verify compliance with the total authorized limit for the repository system | g | | g |
| **Explosive materials** | Explosive materials can destroy the enginnered barriers | NO Explosive | | |
| **Flammable materials** | Flammable materials can destroy the enginnered barriers | NO Flammable | | |
| **Materials that produce gas** | Gaseous waste or materials that can produce gas can induce pressures such as to damage the conditioning matrix and the package. These materials may be forbiden or allowed in small quantities | No gas<br>or<br>g - % | | |
| **Corrosive elements** | The corrosive elements can induce degradation of the conditioning matrix and of the package. They must therefore be restricted in any package | Grams<br>or<br>Volume % | | |
| **Reactive elements** | The reactive elements can induce degradation of the conditioning matrix and of the package. They must therefore be forbiden (strong reactive elements) or restricted in any package | No strong Reactive elements<br><br>Grams or Volume % for Reactive elements | | |
| **Complexing agents** | The complexing elements can favor the leaching of radionuclides. Their quantity must therefore be limited in each packahge | Grams<br>or<br>Volume % | | |

| | | | | |
|---|---|---|---|---|
| **Chelating agents** | The chelating elements can favor the leaching of radionuclides. Their quantity must therefore be limited in each packahge | Grams or Volume % | | |
| **Fermentable elements** | Fermentable substances can generate gases or voids within the package. Their quantity must therefore be limited for each package | Grams or Volume % | | |
| **Putrescible elements** | Materials made from animal remains. They can generate voids inside the package as a result of their disintegration, with the consequent formation of substances that can lead to a degradation of the conditioning matrix. They can also carry a bacteriological and viral risk. | No Putriscibile or Special Treatment | | |
| **Oxidizing elements** | The oxiding elements can induce degradation of the conditioning matrix and of the package. They must therefore be restricted in any package | Grams or Volume % | | |
| **Biological** | They can carry a bacteriological and viral risk | No Biological | | |
| **General** | | | | |
| **Mechanical Characteristics** | | | | |
| **Conditioning process** | The conditioning process (Solution adopted to isolate radioactivity) must be defined in terms of: matrix used for conditioning, type of conditioning (homogeneous or heterogeneous), use of high integrity container with shielding capacity for gamma irradiation or isolation for beta / alpha contamination | Qualitative | | |
| **Qualification of the conditioning process** | The conditioning process must be qualified. This means that the waste matrix (conditioning and waste matrix), container and product must be tested with specific tests in order to ascertain their long-term stability.<br>Some examples of tests that can be performed are:<br><br>- **waste matrix:** Compressive Strength, Thermal Cycling, Radiation Resistance, Biodegradation Resistance, Immersion, Fire Resistance, Permeability, Gas permeability, Leaching rate<br><br>- **Container**: Resistance to degradation, Tightness<br><br>- **Package**: Stacking, Lifting, Free liquids, Gas generation. | Specific limit for each test. | | |
| **Physical Characteristics** | | | | |
| **Solid Waste** | The waste must be described in order to choose the methodologies / techniques to be used to verify its characteristics. The description must concern the physical characteristics, the product category, the mix of different materials. Materials that are not radioactive waste (which could dilute the contamination) and any screens should be excluded | | | |
| **Liquid Waste** | Liquid waste is not accepted. They have to be treated (if necessary) and conditioned | | | |
| **Container** | The container must have structural and physical characteristics such as to guarantee the containment of the waste, help protect against the radiations emitted and promote mobility.<br><br>Some aspect to be considered are: Materials, Geometry and Dimensions, Realease of gas, Resistance to degradation, Decontaminability | | | |
| **Package** | The product must demonstrate that it has chemical, physical and mechanical characteristics such as to guarantee compliance, over time, with a minimum set of requirements.<br><br>Some of these can be: Mass, Outdoor dose rate, Absence of free liquids, Homogeneity of the waste form, Nuclear criticality. | Specific limit for each aspect | | |

## 6 HOW TO TRACK THE CHOSEN WACS

- Availability of historical records on Legacy Waste Streams
- Possible methodologies for deriving the required characteristics on existing legacy waste (to be explored and described in Task4)
- Suggestions to waste producers for recording required characteristics during waste treatment/conditioning

Once that the minimum set of WACs necessary to ensure long-term safety for legacy waste has been identified, the first activity that can be made for the final disposal of legacy waste is to search for any possible historical information and recording regarding these waste streams.

Once all the possible historical information has been found, it is therefore necessary to verify all the missing information that are still necessary for the right management of that particular waste stream.

Right away, based on the type of waste to be dealt, it is important to identify the best methods to measure the missing characteristics for that type of waste.

Sometimes, since some legacy waste had already been treated and/or presents some critical elements, it is not easy to identify the best characterization techniques. In task 4 these problems will be dealt trying to ensure an adequate retrieval of minimum information for the safe management and disposal of this type of waste in the long term.

One thing that can be done as a practice is to record all types of information regarding each step of present and future waste management for every waste stream in order to avoid running into similar problems in the future.

## 7 CONCLUSIONS

A survey has been performed among ERDO and non ERDO members countries, with a particular attention among those countries who owns a national radioactive waste repository in operation or are building it.

Some ERDO countries were usually characterized by small inventories or early-stage waste management programmes, with a not-defined final disposal strategy and so lacking Waste Acceptance Criteria for repositories.

The main problem with such a situation is that there are no clear guidelines for the treatment of radioactive waste produced and even less for the management of legacy waste.

The main objective of the task 2 was therefore to collect information regarding WACs of the countries involved in the research to try to determine a minimum common set of WACs to manage VLLW and LLW waste.

Just two countries responded to surveys sent, so information were collected among free published documents and in the end were gathered some WACs information of about 18 countries.

The research was sorted in a table divided into 4 categories of WAC (radiological, chemical, mechanical and physical).

The research and the analysis revealed many points in common in the declared data of WACs.

Main aspects of WACs concern control and limitation of the radiological and chemical content of waste. The other aspects concern the minimum mechanical characteristics that waste packages must have and the characteristics to easily guarantee that waste can be recognizable and identifiable.

A set of possible WAC/Safety aspect to be verified for Legacy Waste Characterization has been proposed.

The possible methodologies for measuring each aspect, will be verified in the task 4.

## 8 REFERENCES

[R1] PREDIS – Deliverable 2.4 International approaches to establishing a waste acceptance system;

[R2] ROUTES – Milestone 144: Sharing experience on waste management with/without WAC available – Work Package 9;

[R3] CHANCE: Synthesis of Commonly Used Methodology for Conditioned Radioactive Waste Characterization (D2.2);

[R4] Australia – Sandy Ridge Facility Waste Acceptance Criteria – Document No.: DOCID-88105952-980 Final Report August 2016;

[R5] Belgium – ONDRAF/NIRAS: Needs for non-destructive and destructive analysis methods for the physical and radiological controls in relation to the WAC for surface disposal (presentation for IGD-TP);

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[R10] Croatia – International conference: Nuclear Option in Countries with Small and Medium Electricity Grids; Dubrovnik (Croatia); 19-22 Jun 2000 (Metghodology behind radiological WACs);

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[R12] Czech Republic – Radioactive Waste Management: Review on clearance levels

and acceptance criteria legislation, requirementsand standards - Franz-Josef Maringer et al., Hal archives-overture;

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[R17] United Kingdom – LLW Repository Ltd Waste Acceptance Criteria – Metallic Waste Treatment - WSC-WAC-MET Version 3.0 April 2012;

[R18] United Kingdom – Waste Acceptance Criteria – Supercompactable Waste Treatment Waste Services Contract WSC-WAC-SUP – Version 3.0 – April 2012;

[R19] Spain - WM'05 Conference, Feb 27-March 3, 2005 Tucson, AZ: El Cabril Low and intermediate level waste disposal Facility, new acceptance criteria;

[R20] Spain – WAC for storage and disposal of LILW in Spain (Spanish Wac Survey);

[R21] IAEA-TECDOC-1515 Development of Specifications for Radioactive Waste Packages - October 2006;

[R22] IAEA Safety Standards Series SSR 6 (Rev. 1) – Regulations for the safe transport of Radioactive Material;

[R23] DN SM 00008 – Criteri preliminari di Accettabilità al Deposito Nazionale dei rifiuti radioattivi (document on Waste Acceptance Criteria for the Italian near surface disposal facility);

[R24] UNI 12390 3:2009 – Prova sul calcestruzzo indurito – Resistenza alla compressione dei provini;

[R25] Italy – UNI 11193:2006 - Manufatti di rifiuti radioattivi condizionati – Metodi di prova per la qualificazione dei processi di condizionamento per manufatti

appartenenti alla Categoria 2;

[R26] Italy – UNI EN ISO 11599:1997 – Determination of gas porosity and gas permeability of hydraulic binders containing embedded radioactive waste;

[R27] Italy – UNI EN ISO 8990:1999 – Isolamento termico – Determinazione delle proprietà di trasmissione termica in regime stazionario – Metodo della doppia camera calibrata e della doppia camera con anello di guardia;

[R28] ASTM G 2196 – Standard Test Methods for Rheological Properties of Non-Newtonian Materials by Rotational (Brookfield type) Viscometer;

[R29] ASTM G 2276 – Standard Test Method for Particulate Contaminant in Aviation Fuel by Line Sampling;

[R30] ASTM 635 03 – Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Plastics in a Horizontal Position;

[R31] ANSI ANS 16.1:2003 - Measurement Of The Leachability Of Solidified Low-Level Radioactive Wastes By A Short-Term Test Procedure;

[R32] ANSI ANS 55.1:1992 – Solid Radioactive Waste Processing System For Light-Water-Cooled Reactor Plants.

# ANNEX A

## RADIOLOGICAL WAC and SAFETY ASPECTS

| COUNTRY | FACILITY | STATUS | Classification | Radionuclide and radiological limits | Fissile e Fissionable Materials | Sources | Dose Rate | Surface Contamination | Heat | Other |
|---|---|---|---|---|---|---|---|---|---|---|
| **Australia, Sandy Ridge** | Near Surface Disposal Facility, LLW (+ NORM+ chemical) | ? | | **Individual Radionuclide Activity Concentration for:**<br>- Bulk NORM Waste (Bq/g);<br>- sealed sources (Bq/kg) | | Sealed sources will, upon receipt, be stored in the radioactive waste warehouse, unpacked, inspected and verified. After verification, sources will be secured in a 60 L drum inside a 200 L drum. Cement slurry will be added to the 60 L drum to fill all the void spaces and to cover all the items. The cement filled 60 L drums will be placed in the centre of a 200 L drum, which will then be filled with concrete or equivalent materials. | **Dose rate requirements for ILW and LLW transport packages are:**<br>- Non-exclusive use: restricted to ≤ 2mSv/h on surface, and ≤ 0.1mSv/h at 1 meter.<br>- Exclusive use: restricted to ≤10mSv/h on surface, and ≤0.1mSv/h at 1 meter. | **Waste package surface contamination:**<br>- 4 Bq/cm2 for β/γ emitting radionuclides;<br>- 0,4 Bq/cm2 for α emitting radionuclides. | | |
| **Belgium** | Dessel, LILW | Licenced | | 28 essential RN's<br><br>Ra-226 + Th-232 ≤1 Bq/g | Fissile material (criticality risk + safeguard) | | | | | |
| **Bulgaria** | | | | | | | | | | |
| **Canada, Ontario** | Near Surface Disposal Facility, LLW | Planned | | **Limits for Bulk Waste & Non-Leachate Controlled Packaged Waste:**<br>- 100 Bq/g for α radionuclides<br>- 1.000 Bq/g for long-lived β/Y radionuclides (t1/2 > Cs-137)<br>- 10.000 Bq/g for short-lived β/Y radionuclides (t1/2 ≤ Cs-137)<br>- 100.000 Bq/g for H-3<br><br>**Limits for Leachate Controlled Packaged Waste:**<br>- 400 Bq/g for α radionuclides<br>- 10.000 Bq/g for long-lived β/Y radionuclides (t1/2 > Cs-137)<br>- 10.000 Bq/g for Cs-137)<br>- 10.000 Bq/g for Sr-90<br>- 10.000.000 Bq/g for H-3 | Limits for Special Fissionable Material in Waste Placement<br><br>Highly water soluble forms of Special Fissionable Material shall not be accepted for disposal. | | | External non-fixed surface contamination on Waste Packages must be less:<br>- 3,7 Bq/cm$^2$ for β/γ emitting radionuclides;<br>- 0,37 Bq/cm$^2$ for α emitting radionuclides. | | |
| **Croatia** | To be defined | In study | LILW containing radionuclides with a half life less than 30 years | Alpha emitter activity is limited to 4.000 Bq/g | | | **Dose rate:**<br>- Surface < 2 mSv/h<br>- At 2 m distance < 0,1 mSv/h | **Waste package surface contamination:**<br>- 4 Bq/cm$^2$ for β/γ emitting radionuclides;<br>- 0,4 Bq/cm$^2$ for α emitting radionuclides. | | LILW must have radiation stability so cumulative dose ≤ $10^6$ – $10^7$ Gy |

| COUNTRY | FACILITY | STATUS | Classification | Radionuclide and radiological limits | Fissile e Fissionable Materials | Sources | Dose Rate | Surface Contamination | Heat | Other |
|---|---|---|---|---|---|---|---|---|---|---|
| **Czech Republic** | Litomerice | Operational | | **Activity of unsolidified waste in a double overpacks and solidified RAW in a simple overpacks (Bq):**<br>- H3=2.0E+12; Sr90=3.0E+11; Cs137=3.0E+10.<br>- C14=6.0E+09; Cl36=2.0E+08; Tc99=1.0E+08; I129=4.0E+06.<br>- Long Lived Alpha emitting Rn=2 .0E+07<br><br>**Activity of solidified waste in a double overpacks (Bq):**<br>- H3 = 1.0E+13; Sr90 = 3.0E+11; Cs137 = 1.0E+11.<br>- C14 = 3.0E+10; Cl36 = 1.0E+09; Tc99 = 5.0E+08; I129 = 2.0E+07.<br>- Long lived Alpha emitting Rn = 1.0E+08<br><br>**The activity of lump RAW (Bq/kg):**<br>- H3=3.0E+09; Sr90=1.0E+08; Cs137=1.0E+08;<br>- C14=1.0E+07; Cl36=3.0E+06; Tc99=1.0E+05; I12 =1.0E+04;<br>- Long-lived Alpha emitting Rn=3.0E+04 | | | | **Waste package surface contamination:**<br>- 0,3 Bq/cm2 for β/γ emitting radionuclides.<br>- 0,03 Bq/cm$^2$ for α emitting radionuclides; | | |
| **France** | l'Áube, LILW, near surface | Operational | | The radionuclides of which the total quantity (Bq) and the quantity per package (Bq/g) accepted for disposal is limited, was: 3H, 14C, 22Na, 36Cl, 41Ca, 54Mn, 55Fe, 59Ni, 60Co, 63Ni, 65Zn, 79Se, 90Sr, 93Zr, 93Mo, 94Nb, 99Tc, 106Ru, 107Pd, 108mAg, 119mSn, I25Sb, 129I, 134Cs, I35Cs, 137Cs, 144Ce, 147Pm, 152Eu, 204Tl, 210Pb, 227Ac, 234U, 237Np, 238U, 238Pu, 239Pu, 240Pu, 241Am, 241Pu, | | | | | | |
| **Germany** | Konrad, LLW, near surface | Operational | | Limits on radiation activity (total alpha and total beta activity, activity for a series of radionuclides plus U-total, Pu-total activities) | | | Gamma & neutron dose rate at container surface and 1m distance | | Total heat-power per container and container-averaged heat decay constant.K15 | |
| **Hungary** | Püspökszilágy | Operational | | **Maximum activity-concentration (Bq/drum):**<br>3H=7.32E+13, 14C=5.58E+12, 36Cl=5.20E+09, 54Mn=1.34E+11, 55Fe=1.01E+12, 58Co=2.80E+12, 59Ni=5.70E+12, 60Co=1.99E+10, 63Ni=2.40E+12, 90Sr=1.72E+10, 94Nb=2.34E+10, 99Tc=3.24E+11, 110mAg=4.46E+11, 124Sb=2.02E+11, 129I=2.62E+09, 134Cs=1.03E+10, 137Cs=1.36E+10, 141Ce=2.80E+13, 144Ce=2.80E+13, 234U=1.02E+10, 235U=4.36E+10, 238U=2.94E+10, 238Pu=1.28E+10, 239Pu=1.14E+10, 240Pu=2.80E+11, 241Am=1.42E+10, 242Cm=2.22E+11, 243Am=1.41E+10, 244Cm=2.30E+10<br><br>**Limit the activity concentration of individual waste packages:**<br>- for isotopes with half-lives of 5-6 years < to the upper limit of intermediate level waste category<br>- for isotopes with halsf-lives of 6-30 years < 5×10$^6$ Bq/g.+<br><br>**Average concentration for the whole facilit**y < of the limit of LLW category. | | | Contact dose rate < 10 mSv/h on the drum's surface | **Surface contamination of an overpack with RAW must not exceed:**<br>- 4 Bq/cm$^2$ for β/γ emitting radionuclides;<br>- 0,4 Bq/cm$^2$ for α emitting radionuclides. | If the heat generation is higher than 20 W/m3, the effects must be analysed | |

| COUNTRY | FACILITY | STATUS | Classification | Radionuclide and radiological limits | Fissile e Fissionable Materials | Sources | Dose Rate | Surface Contamination | Heat | Other |
|---|---|---|---|---|---|---|---|---|---|---|
| **Italy** | Near Surface disposal facility (for VLLW and LLW) | In study | The classification include:<br>- VLLW (Short lived Rn total A < 100 Bq/g)<br>- LLW (short lived Rn with A < 5 MBq/g and long lived Rn with A < 400 Bq/g)<br>- ILW (short lived Rn with A > 5 MBq/g and long lived Rn with A > 400 Bq/g)<br>- HLW (spent fuel or vitrified fuele reprocessing residue)<br><br>No classification for radioactie sealed sources | **At the near surface disposal facility will be accepted only waste packages with activity concentration of radionuclides:**<br>- short lived (with half life < 31years) <= 5 MBq/g<br>- long lived (with half life > 31years) <= 400 Bq/g<br>- Ni59/Ni63 <= 40 kBq/g | | Disused sealed sources disposal will have to be assessed on a case-by-case basis | **Dose rate:**<br>- on surface < 2 mSv/h<br>- at 2 m distance < 0,1 mSv/h | External non-fixed contamination levels on the Transport Container at the time of consignment shall be as low as reasonably practicable and in any case, not more than:<br>- 0.4 Bq/cm$^2$ for all α-emitting radionuclides<br>- 4 Bq/cm$^2$ for all other radionuclides | At the repository will not be accepted heat producing waste | |
| **Iran** | | | | In the near surface disposal facility, it is not permitted to dispose High-level and long-lived waste | | | | | | |
| **Lithuania** | LILW near surface facility | | Radioactive waste are classified in:<br>- VLLW-SL (Class A)<br>- LILW-SL (Class B + C)<br>- LILW-LL (Class D + E) and<br>Spent Sealed Sources (Class F) | | | | | | | |
| **Poland** | Rozan | Operational | | Radiological parameters in WAC are specified the radionuclide composition and characteristics (very low and low level waste; short and long-lived radionuclides) | | | Maximum gamma dose rate on the surface of packaging and at the 1 m distance | Unbounded contamination on the packaging surface. | | |
| **Romania** | Cernavoda | Operational | | Max limits are imposed for a list of individual radionuclides. | Radioactive waste containing fissile radionuclides are not accepted for disposal. | | Contact gamma dose rate is limited by the transport norms and for operator safety. | Surface removable contamination of the waste packages is limited by the transport norms and for operator safety. | | |
| **Slovakia** | Mochovce, near surface LILW | Operational | | Basic limitations on the acceptability of waste for near surface disposal include the specific activities and total quantities of radionuclides in the waste as they were determined on a basis of sitespecific long term safety assessment for the following 19 nuclides: 1l4C, 41Ca, 59Ni, 63Ni, 79Se, 90Sr, 93Mo, 93Zr, 94Nb, 99Tc, 107Pb, 126Sn, 129I, 135Cs, 137Cs, 151Sm, 238Pu, 239Pu and 241Am.<br><br>Short term safety assessment (handling, transport) was performed for next three nuclides: 3H, 55Fe and 60Co. | | | | | | |
| **Spain** | El Cabril, LILW | Operational | | **Level 1 (Bq/g):**<br>- Total alpha <1.85×10$^2$;<br>- 3H<7.4×10$^3$; 60Co<3.7×10$^3$; 137Cs<3.7×10$^3$;<br><br>**Level 2 (Bq/g):**<br>- Total alpha <3.7×10$^3$;<br>- 3H<1×10$^6$; 60Co<5×10$^7$; 137Cs<3.3×10$^5$ | | | | | | |
| **Switzerland** | | | | | | | | | | |

| COUNTRY | FACILITY | STATUS | Classification | Radionuclide and radiological limits | Fissile e Fissionable Materials | Sources | Dose Rate | Surface Contamination | Heat | Other |
|---|---|---|---|---|---|---|---|---|---|---|
| **United Kingdom (combustible waste treatment)** | Drigg | Operational | | **Activity Limits for Combustible Waste Packages are for acceptance:**<br>- Alfa < 0,5MBq; C14 < 3.000 MBq; H3 < 40.000 MBq;<br>- All other Beta/Gamma < 10MBq.<br><br>**Activity limits for likely to be accepted are:**<br>- Alfa < 8MBq;<br>- All other Beta/Gamma < 40 MBq.<br><br>**Activity limits for maybe accepted are:**<br>- Alfa < 15 MBq; C14 < 100.000 MBq; H3 < 100.000 MBq;<br>- All other Beta/Gamma < 8.000 MBq.<br><br>**Where waste arising from the Combustible Waste treatment service** is to be disposed of as Secondary Waste at the LLW Repository, the activity of any Waste consignment shall not exceed the following values:<br>- 4 GBq/t for all Alpha-emitting radionuclides<br>- 12 GBq/t for all other radionuclides | | **This object are restricted**:<br>- Sources (ceramic beads, pellets or smoke detectors);<br>- radioactive lightening conductors;<br>- Anti-static devices containing radiation source | The dose rate limit for a Waste Package must not exceed 7.5 µSv/h.<br>The maximum radiation level at any point on the external surface of the Transport Container shall not exceed 2 mSv/h and 100 µSv/h at 2 metres. | External non-fixed contamination levels on the Transport Container at the time of consignment shall be as low as reasonably practicable and in any case, averaged over an area of 300 $cm^2$, not more than:<br>- 0.4 $Bq/cm^2$ for all α-emitting radionuclides<br>- 4 $Bq/cm^2$ for all other radionuclides | | |
| **United Kingdom (metallic waste treatment)** | | | | **Activity Limits for Metallic Waste Items are for acceptance:**<br>- All Alfa < 0.5 GBq/t;<br>- Il Beta/Gamma < 0.5 GBq/t.<br><br>**Activity limits for likely to be accepted are:**<br>- All Alfa < 1 GBq/t;<br>- All Beta/Gamma < 10 GBq/t.<br><br>**Activity limits for maybe accepted are:**<br>- All Alfa < 4 GBq/t;<br>- All Beta/Gamma < 12 GBq/t.<br><br>**Where waste arising from the Metallic Waste treatment service** is to be disposed of as Secondary Waste at the LLW Repository, the activity of any Waste consignment shall not exceed the following values:<br>- 4 GBq/t for all Alpha-emitting radionuclides<br>- 12 GBq/t for all other radionuclides | | Sealed Sources are restricted | The average surface dose rate of any Waste Item must not exceed 0.2 mSv/h.<br>The maximum radiation level at any point on the external surface of the Transport Container shall not exceed 2 mSv/h and 100 µSv/h at 2 metres. | Items will be acceptable if the maximum external non-fixed contamination on surface is less than:<br>- 5 $Bq/cm^2$ for all α-emitting Rn<br>- 100 $Bq/cm^2$ for all other Rn.<br><br>Service Supplier specific criteria may apply. Specific restrictions will be determined through the Waste Enquiry Process.<br><br>External non-fixed contamination levels on the Transport Container at the time of consignment shall be as low as reasonably practicable and in any case, averaged over an area of 300 cm2, not more than:<br>- 0.4 $Bq/cm^2$ for all α-emitting Rn<br>- 4 $Bq/cm^2$ for all other Rn | | |
| **United Kingdom (supercompaction waste treatment)** | | | | **The Activity of any Waste Consignment consigned** for disposal as LL W at the LLW Repository shall not exceed the following values:<br>- 4 GBq/t for all alpha-emitting radionuclides<br>- 12 GBq/t for all other radionuclides<br><br>**Some radionuclide limits:**<br>- Waste shall not contain Th-232 in excess of 1 MBq/t.<br>This limit may be exceeded but only on approval of a Waste Consignment Variation Form<br>- Waste containing Am-241, Am-242m and / or Am-243 may be consigned if the Consignment does not contain more than 0.1 GBq/t of each of these radionuclides.<br>- Waste containing Np-237 may be consignedif the Consignment does not contain more than 4 GBq/t<br>- Waste containing plutonium may be consigned if the Consignment if the total Pu Alpha (i.e. Pu-238 + Pu-239 + Pu-240 + Pu-242) does not exceed 0.1 GBq/t.<br>- Waste containing U-235 may be consigned if the Consignment meets the following requirements:<br>• All the uranium present is either natural or depleted uranium, or<br>• The U-235 content of any Waste Consignment does not exceed 60 g | | | | | | |

## CHEMICAL WAC and SAFETY ASPECTS

| COUNTRY | Organic material | Hazardus/Toxic material (Heavy Metals, Volatives, Pesticides) | Explosive materials | Flammable materials | Materials that produce gas | Corrosive elements | Reactive elements | Complexing agents | Chelating agents | Fermentable elements | Putrescible elements | Oxidizing elements | Biological | General |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Australia, Sandy Ridge** | | | | Flammable materials are exclused | | Non-reactive | | | | | | | | All LLW and ILW waste packages will be chemically stable and safe for disposal in the LLW vaults.<br><br>If chemicals with harmful properties are in waste, they have to treated and/or limited.<br><br>Dilution with non-waste material has to prevented.<br><br>The hazard categories which will be controlled are reactive, explosive, oxidising, corrosive, chelating, chemotoxic and hazardous properties.<br>The requirement is to make such materials passively safe (so the waste packages do not require human actions to be safe). |
| **Belgium** | Max. 100 g of cellulose per waste drum | | | | Maximum 12 g sulphates per kg of waste | Mass of chloride in waste ≤ 0,4 m.% of cement mass | | | | | | | | |
| **Bulgaria** | | | Explosive materials: these are not allowed in the waste. | Combustibility and fire-resistance: waste forms shall be packaged in such a manner and have such characteristics that the risk of self-ignition is negligible. | | | Chemical reactivity: substances that might jeopardize the stability of the waste packages or the barrier functions of the repository are not allowed. | The complexing agents also shall be avoided as far as possible. | | | | | | |
| **Canada, Ontario** | | Hazardous waste are not permitted unless they are treated using methods for land disposal described in Ontario Regulation 347 | | Ignitable waste are not permitted unless they are treated using methods for land disposal described in Ontario Regulation 347 | | Corrosive waste are not permitted unless they are treated using methods for land disposal described in Ontario Regulation 347 | reactive waste are not permitted unless they are treated using methods for land disposal described in Ontario Regulation 347<br><br>Fluorine, Magnesium and Bismuth are restricted to ≤ 20% by mass over a single waste unit (i.e. 1500 kg).<br><br>Beryllium, Deuterium and Graphite are restricted to ≤ 0.1% by mass combined over a single waste unit (i.e. 1500 kg) | | Chelating agents in waste shall be restricted to less than 0.1% by mass over a single waste unit (i.e. 1500 kg) | | | | | |
| **Croatia** | Organic material content must not exceed 3% of the package weight. | For toxic/hazardous substances, depending on the type of hazardous material the limitation should be taken from the relevant regulations. | No explosive substances | Self-ignitable, easy ignitable and ignitable materials are not permitted in LILW. | Depending on type of gas and mixture, limitation must be below lower limit of explosivity/ignitability | **pH value must be**:<br>- 4 < pH < 9 for waste form,<br>- < 11 for cement.<br><br>**Corrosive materials** content must be ≤ 1% of package weight. | | Chelating and complexing agents must be ≤ 0,1% package weight. | | | | | | |
| **Czech Republic** | | | | | | | | | | | | | | |
| **France** | | | | | | | | | | | | | | |

| COUNTRY | Organic material | Hazardus/Toxic material (Heavy Metals, Volatives, Pesticides) | Explosive materials | Flammable materials | Materials that produce gas | Corrosive elements | Reactive elements | Complexing agents | Chelating agents | Fermentable elements | Putrescible elements | Oxidizing elements | Biological | General |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Germany** | | Chemical toxicity & hazards have to be considered | | No flammble materials | No gas | Corrosion has to be controlled (humidity) | | | | | | | | No swelling are admitted<br>No chemical kinetics are acceptable.<br>Nuclide vector and material vector (metallic, ceramics, rubble) have to be declared. |
| **Hungary** | | | | | Gas generation Hydrogen and other explosive gases organic and elementary gases: Pressure higher than 0.5 bar cannot occur | Corrosive materials: Less than 1% weight | | Chelating and complexing agents: Max. 0.5% of the waste being conditioned | | | | | | |
| **Italy** | | inventory of the CMR substances (carcinogenic, mutagen, toxic for reproduction) present in the waste is needed | Waste shall not contain strong reactive retals, explosive, strong oxidising agents, pressurised gas receptacles and aerosols, ion exchange material, biological, pathogenic or infectious materials.<br>Quantities of this materials must be limited for waste package: complexing and chelating agents, organic, powders, fibers and ceramics, oils and paraffins, absorbent materials, soluble | | | | | | | | | | | |
| **Iran** | | Chemical substances of toxic characteristics, corresponding to class (extremely hazardous) and class II (highly hazardous) of hazard; | Conditioned waste packages shall not contain Substances capable of detonation or explosive decomposition; | Conditioned waste packages shall not contain Flammable and explosion- and fire hazardous substances; | Conditioned waste packages shall not contain Substances that contain or are capable of generation gasses, vapours or sublimates resulting in loss of integrity of engineering barriers | Conditioned waste packages shall not contain Corrosion-active substances of concentration that may result in corrosion destruction of containers, disposal cells and other components of the waste NSSF | Conditioned waste packages shall not contain Substances, entering into exothermic reaction with water, that is accompanied by the explosion | Conditioned waste packages shall not contain Substances forming complex compounds of concentration, that may sufficiently impact on the processes of radionuclides migration into the environment | | | | Conditioned waste packages shall not contain Strong oxidants and chemically unstable substances; | Conditioned waste packages shall not contain Poisonous, pathogenic and infectious substances, Biologically active substances | |
| **Lithuania** | | | | | | | | | | | | | | |
| **Poland** | Waste containing following substances shall be stored separately from each other and from the waste:<br>- organic solvents,<br>- extractants and oils<br>- detergents in concentration exceeding 10 mg/dm$^3$ | | | | | | | Waste containing following substances shall be stored separately from each other and from the waste:<br>- complexing agents in concentration exceeding 10 mg/dm3<br>- dissolved substances and deposits with content of dry residue exceeding 10 g/dm3 | | | | | | |

| COUNTRY | Organic material | Hazardus/Toxic material (Heavy Metals, Volatives, Pesticides) | Explosive materials | Flammable materials | Materials that produce gas | Corrosive elements | Reactive elements | Complexing agents | Chelating agents | Fermentable elements | Putrescible elements | Oxidizing elements | Biological | General |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Romania** | The waste that are accepted with restriction, based on a case by case decision are wood | | Compounds which present alone or in contact with air or water, risks of explosion or ignition are forbidden to be disposed.<br><br>The auto-ignition temperature of all waste shall not be less than 300°C. | | The waste that contain or are capable of generating toxic gases, vapours or smoke during transport, handling or storage are not admitted for disposal. | | Compounds which present alone or in contact with air or water, risks of reaction as alkali metals, metal fines, powdery magnesium, uranium, aluminium, explosives, unstable chemicals, strong reducers (hydrazine, borohydride, fuel, alcohol, phosphorus…) are forbidden to be disposed.<br><br>The waste that are accepted with restriction, based on a case by case decision are waste which react with the matrix, waste which react with water (aluminium, zinc, uranium, magnesium) | | The waste that are accepted with restriction, based on a case by case decision are chelatants | | | | Radioactive waste containing hazardous, biological (organic), pathogenic or infectious agents must be treated, conditioned and packed in such a way as to minimize the danger that would be caused by the disposal of these types of waste. | |
| **Slovakia** | | | | | | | | | | | | | | |
| **Spain** | RW producers sent yearly information on chemical analyses of the main components of the LLW homogeneous wet waste (evaporator bottoms and sludge). This information will assure the waste meets following limitations or must notification:<br>- organic substances: EDTA, NTA, DTPA, TTHA, oxalates, citrates, acetates, TBP, ethylene, diamine…etc., others like sulfonates;<br>- organic liquids conditioned by incorporation into a solid matrix of hydraulic binder, should not contain organic liquids above 3% by volume of matrix. | An inventory of the toxic substances present in the storage is needed, and the producers must submit to ENRESA annually, the contents of the following elements: lead, copper, aluminium and asbestos. | Explosive material are forbiden | Easily flammable or flammable Material are forbiden | Waste with animals have to be treated to prevent the generation of gas<br><br>Waste with gas (neon tubes, non-empty aerosols, etc.) are forbiden | Corrosive material are forbiden. | Pyrophoric or strongly reactive metallic materials (magnesium powder, sodium or sodium alloys). | RW producers sent yearly information on chemical analyses of the main components of the LLW homogeneous wet waste (evaporator bottoms and sludge). This information will assure the waste meets following limitations or must notification accelerators of leaching processes: the producer will identify, before packaging, waste containing complexing agents above 8%, such as chlorides, fluorides, nitrates, sulphates, carbonates; | | Fermentable materials are limited above 3% by total mass of the batch of packages (WAC specific for VLLW), or 10% by individual package (both types) | Waste with animals have to be treated to prevent the generation of gas. | Oxidizing material are forbiden. | Infectious products are forbiden. | |
| **Switzerland** | | | | | | | | | | | | | | |

| COUNTRY | Organic material | Hazardus/Toxic material (Heavy Metals, Volatives, Pesticides) | Explosive materials | Flammable materials | Materials that produce gas | Corrosive elements | Reactive elements | Complexing agents | Chelating agents | Fermentable elements | Putrescible elements | Oxidizing elements | Biological | General |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **United Kingdom (combustible waste treatment)** | **There is a list of solid materials that are restricted**: PCBs,<br><br>**There is a list of solid materials that are provisionally acceptable**: Plastics (halogenated including PVC); Rubber; Grease | There is a list of solid materials that are restricted: Toxic materials (including mercury, PCBs, cyanides); Asbestos; Metal (including steel, lead, chromium, cadmium, mercury, beryllium, uranium metal, thorium metal). | Pyrophorics or explosive substances including free sodium are restricted | | Pressurised gas receptacles or aerosols are restricted | | | | | | Putrescent material including carrion are provisionally acceptable | | Biological, Infectious or Pathogenic materials, are restricted. | **There is a list of solid materials that are restricted**: Concrete; Blasting materials (including sand, grit, glass, beads, pearls); Materials with sharp edges such as knives, glass, needles; Luminous items.<br><br>**There is a list of solid materials that are provisionally acceptable**: Filters; Graphite; Cables and thin gauge metals; Fibreglass, Mineral wool; Halogenated waste; Ion exchange resins; Mud (non-pumpable). |
| **United Kingdom (metallic waste treatment)** | Non-metallic materials such as rubber; plastic or other organic materials are restricted | Toxic and hazardous materials and wastes (as Mercury and asbestos) are restricted | Explosives are restricted. | Self-igniting are restricted. | Pressurised containers e.g. redundant gas bottles and fire extinguishers are restricted. | | Reactive metals or materials are restricted. | Complexing agents are restricted. | Chelating agents are restricted. | | Putrescible Waste are restricted. | Strong Oxidising Agents are restricted. | Biological, Infectious and Pathogenic Materials are restricted. | **There is a list of solid metalic materials that are restricted**: Zinc galvanised metal<br><br>**There is a list of solid non metalic materials that are restricted**: Soluble Solids; Bituminous or other linings; Boron; Armoured cables; Pyro-cables and cables containing tensioning wires; Ion exchange resins; organic as well as inorganic resins; Cans of paint; grease; aerosols. |
| **United Kingdom (supercompaction waste treatment)** | | Materials that are likely to, or actually, possess one or more Hazard Properties shall be assessed and where present be excluded from the waste or made safe prior to any conditioning or mixing with other materials.<br><br>Customers should use process knowledge to demonstrate that materials do not contain the components listed in a Table (limits for leaching tests) before resorting to material testing.<br><br>For the material to be made safe, the hazards or risks shall be removed or reduced.<br><br>Waste containing Hazardous Substances and Non-Hazardous Pollutants may be accepted for treatment and disposal but only on approval of a Waste Consignment Variation Form<br><br>Waste containing lead may be accepted for treatment and disposal but only on approval of a Waste Consignment Variation Form | Waste shall not contain explosive material. | | Waste shall not contain pressurised gas receptacles. | | Waste shall not contain reactive retals. | Waste shall not contain chemical complexing agents. | Waste shall not contain chelating agents. | | Putrescible Materials in the waste and, in any case, the total weight within a Waste Consignment must not exceed 1% of the total weight of waste. | Waste shall not contain strong oxidising agents. | Waste shall not contain biological, pathogenic or infectious materials. | Waste shall not contain soluble solids, ion exchange material. |

## MECHANICAL WAC and SAFETY ASPECTS

| COUNTRY | Conditioning process | Qualification of the conditioning process |
|---|---|---|
| **Australia, Sandy Ridge** | Wasteforms (the physical form of the waste following treatment/conditioning) must be physically solid and stable, and resistant to degradation. | |
| **Belgium** | Mass of hardened cement ≥ 10 m.% of cement mass<br><br>Minimum amount of conditioning mortar: 85%<br><br>Immobilisation matrix unsensitive to ASR/DEF | |
| **Bulgaria** | | Leaching properties have to be in accordance with the requirements for long-term safety of the repository. |
| **Canada, Ontario** | | |
| **Croatia** | Treatment and conditioning technologies must be approved by the regulatory body.<br><br>LILW must be evenly distributed in metal and concrete container. Heterogeneous and non conditioned LILW is not allowed to be disposed. | **Proposed value for the compressive strength of LILW for**:<br>- waste form is 5 Mpa;<br>- concrete container 60 MPa.<br><br>**Tensile strength for**:<br>- waste form should be 1 Mpa;<br>- concrete container 5,5 MPa.<br><br>LILW must be resistant to thermal cycles. Thermal cycles are referred to temperature differences in the range between -40 to +60°C<br><br>For permeability, an orientation limit of 5x10e-18 m2 (nitrogen) is proposed.<br><br>Porosity is suggested not to exceed the value of 0,5% of the RCC volume.<br><br>Leachability index (LIX) LIX ≥6, za diffusion coefficient 5×10-3 cm2/day, a leachability rate 3×10e-5 g/cm2/day. |
| **Czech Republic** | | |

| COUNTRY | Conditioning process | Qualification of the conditioning process |
|---|---|---|
| **France** | | |
| **Germany** | All RW have to be solidified<br><br>The grouting material is concrete | No leaking and no leaching are acceptable. |
| **Hungary** | | Compressive strength is greater than 10–30 $N/mm^2$<br><br>Leaching rate: Max. 5*10-5 g/cm2 s<br>(evaluated based on ASTM C1308-95 standard) |
| **Italy** | | **Cement waste form qualification tests for LLW waste**:<br>- Compressive Strength: After 28 days curing f c 5 Mpa<br>- Thermal Cycling: After 30 cycles (+40 C ÷ 40 C) there must be no cracks and f c 5 MPa Radiation<br>- Resistance: After an integrated gamma dose of $10^6$ Gy there must be no cracks and f c 5 MPa<br>- Biodegradation Resistance: After fungi and bacteria incubation there must be no cracks and f c ≥ 5 MPa<br>- Immersion: After 90 days of immersion in water there must be no swelling or cracks and f c ≥ 5 MPa<br>- Gas generation: Identification and quantification of gases produced by radiolysis or other chemical physical reactions<br>- Fire Resistance: Incombustible or self extinguishing - Water<br>- Permeability: Water penetration 20 mm<br>- Gas permeability: must be evaluated<br>- Leaching rate: Li ≥ 6 for Cs 137 |
| **Iran** | | |
| **Lithuania** | | |
| **Poland** | | The rate of leaching with distilled water of solidified radioactive waste, after 28 days of leaching in static conditions, cannot exceed the prescribed levels depending on waste classification |

| COUNTRY | Conditioning process | Qualification of the conditioning process |
| --- | --- | --- |
| **Romania** | **No raw waste is accepted for disposal**:<br>- Homogeneous waste has to be solidified;<br>- heterogeneous waste has to be immobilised. | |
| **Slovakia** | | |
| **Spain** | **Level 2 RW, the WAC require the assurance for activity confinement**:<br>- for compactable waste - packages are super compacted and immobilized CE-2a container with a shield higher than 5 cm thickness of hydraulic binder (the same shield thickness is required for cartridge filters and dispersible waste;<br>- for non-compactible waste – the gaps in packages are filled with hydraulic binder of 30 kg/cm2 compression resistance, before to be conditioned in CE-2a concrete container with a shield above 5 cm thickness of hydraulic binder;<br>- cartridge filters and dispersible waste are immobilized in metallic containers (packages), with a shield thicker than 5 cm of hydraulic binder (250 kg/cm2 compression resistance; flex traction or indirect traction ≥ 10 kg/cm2; resistance to nuclides diffusion, values are transformed at leaching rate in aqueous medium;<br>- wet homogenous waste (spent resins, evaporator bottoms, sludge) - are conditioned by incorporation into matrix of hydraulic binder, which need to meet specific criteria regarding the compression resistance, compression after 7 days of water immersion and, flex traction (indirect traction). | **Level 1 RW mechanical strength is limited**:<br>- compactable waste - packages are super compacted (1,200Tn pressure) and immobilized (with hydraulic binder of 30 kg/cm2 compression resistance), in concrete container called CE-2a (7 cubic meter infernal capacity);<br>- non-compactable waste – the gaps in packages are filling with hydraulic binder of 30 kg/cm2 compression resistance, before to be conditioned in CE-2a concrete container;<br>- cartridge filters and dispersible waste are immobilized in metallic containers (packages), with a shield above 5 cm thickness of hydraulic binder (75 kg/cm2 compression resistance), before to be conditioned in CE-2a concrete container;<br>- wet homogenous waste (spent resins, evaporator bottoms, sludge) - are conditioned by incorporation into hydraulic binder matrix, which need to meet specific criteria for compression resistance and compression after 7 days water immersion. |

| COUNTRY | Conditioning process | Qualification of the conditioning process |
| --- | --- | --- |
| **Switzerland** | | **For cemented waste:**<br>- After hardening, waste product samples are exposed to mechanical loading.<br>- The samples have to withstand a minimum load of 10 MPa.<br><br>**Leaching**:<br>Leach rates for the key test nuclides Co-60 and Cs-137 determined over a period of 150 days should be below 5 E-6 m/day. Tests are performed in demineralised and saturated gypsum water.<br><br>**For cemented waste** - Water (and sulphate) resistance: Investigation of the stability of waste products upon water infiltration. Only when the compressive strength of the sample exposed to an aqueous medium is (still) above 10 MPa and the volume increase is less than 5% is the waste product considered water- (and sulphate-) resistant.<br><br>**For bituminized and polystyrene waste**, the following information are required: Flash burning, ignition point; Softening point; Viscosity. |
| **United Kingdom (combustible waste treatment)** | | |
| **United Kingdom (metallic waste treatment)** | | |
| **United Kingdom (supercompaction waste treatment)** | | |

## PHYSICAL WAC and SAFETY ASPECTS

| COUNTRY | Solid Waste | Liquid Waste | Container | Package |
|---|---|---|---|---|
| **Australia, Sandy Ridge** | **For Safeguards material**: Australian Safeguards and Non-proliferation Office (ASNO) approval is required for conditioning - Safeguards material shall be available on request for international inspection. | Containers with liquid are not accepted | For ILW, including all disused sealed sources and safeguards material, container shielding can be used to comply with radiation dose requirement. | • Not have a total measured weight of more than the Safe Working Load.<br>• Be clearly labelled with the waste owner's name and identification number and material description/name on opposite sides of the waste package.<br>• Allow no leakage during normal transport and handling operations.<br>• Be capable of containing all the waste whatever the orientation of the package.<br>• Be capable of being disposed of with the waste.<br>• Be filled so as to contain no significant voids.<br>• Be free of ruptures at the point of delivery.<br>• Be free of external contamination at the point of delivery.<br>• Not significantly deteriorate during the duration of storage, transport and handling when in contact with the waste.<br>• Remain intact during normal transport and handling procedures.<br>• Be strong enough to be walked on if required.<br>• For ILW, including all disused sealed sources and safeguards material, the waste package identifier will be readable for an extended period of around 50 years. |
| **Belgium** | | No free liquids | | |
| **Bulgaria** | | | | |
| **Canada, Ontario** | 6 types of waste based on physical properties<br><br>Special Waste and Waste Electrical and Electronic Equipment (WEEE) will likely require additional processing to ensure compliance with land disposal requirements prior to placement; therefore, all Special Waste and WEEE is to be segregated from other waste streams and clearly labelled. | | | |

| COUNTRY | Solid Waste | Liquid Waste | Container | Package |
|---|---|---|---|---|
| **Croatia** | Density and weight of LILW must ensure structural stability. | Free liquid content ≤ 1% package volume. | Depends on choice of storage-disposal container. The orientation limit for weight of filled container is 15 t or ~3,5 t/m3 density.<br><br>Metal containers and waste package should withstand external fire. According to IAEA recommendations for transport of LILW packages (30 min at a 800 °C temperature) | Waste packages must be labeled in accordance with the requirements of the regulatory body.<br><br>Structural stability of disposal units for 300-year period must be ensured |
| **Czech Republic** | | | | |
| **France** | | | | |
| **Germany** | | No liquid | Mass, size, centre of mass, container type/category<br><br>Drop, fire, pressure, explosion, collision, resilience | Craning, stacking… |
| **Hungary** | **Homogeneity:**<br>The waste types cannot be mixed. This can be accomplished by sorting and separately packaging the single waste types<br><br>**Dust Content:**<br>- Maximum 1 % of particles smaller than 10 µm;<br>- Maximum 15 % of particles smaller than 100 µm. | Free liquid: Max. 1 volume% | | Void volume max. 10% |
| **Italy** | | No free liquids | Weight limit on waste container | **Each waste package must be equipped with a specific label / identification code (possible barcode) that allows**:<br>1) an easy and immediate identification of the artifact and of the waste that<br>contains the link to more detailed waste information (including photographic);<br>2) the traceability of processes applied to waste.<br><br>**Control of the barycenter of the waste package**<br><br>**Voids for waste package must be**:<br>- homogeneous conditioning <5%<br>- heterogeneous conditioning <10% |

| COUNTRY | Solid Waste | Liquid Waste | Container | Package |
|---|---|---|---|---|
| **Iran** | | Content of liquid in the package shall not exceed 3%. | | |
| **Lithuania** | | | | |
| **Poland** | | Unbounded water < 1% mass | | |
| **Romania** | | The solid or solidified radioactive waste has to contain as less as possible free liquid (max 1% from their volume) and this free liquid has to be noncorrosive.<br><br>The liquid radioactive waste has to be solidified or packaged in sufficient absorbent material that is capable of absorbing a volume twice as large as the liquid volume. | | A maximum of 10 % (volume) of voids is allowed in packages. |
| **Slovakia** | | | | |
| **Spain** | **The following material are forbiden**:<br>- Dusty materials that are not conditioned in suitable packaging to prevent their dispersion under the handling and storage conditions;<br>- Waste whose temperature is higher than 60˚ C; | | | |
| **Switzerland** | | | | |

| COUNTRY | Solid Waste | Liquid Waste | Container | Package |
|---|---|---|---|---|
| **United Kingdom (combustible waste treatment)** | Where materials must be added to the waste, the customer shall use reasonable means to limit the quantity of non-waste materials present in a Waste Consignment. It is not acceptable to purposely dilute waste or add shielding materials for the sole purpose of achieving compliance with the requirements of WAC | **There is a list of liquid materials that are provisionally acceptable**:<br>- Liquids containing suspended solids;<br>- Sludge (packaged);<br>- Borated concentrates;<br>- Paint;<br>- Fire resistant oils based on phosphate esters or equivalent. | | |
| **United Kingdom (metallic waste treatment)** | Reasonable means shall be used to segregate Metallic Waste into the following categories within a Waste Consignment: Stainless Steel, Carbon Steel, Galvanised Steel, Cast Iron, Lead, Copper, Aluminium, Brass | Free liquids are restricted | | |
| **United Kingdom (supercompaction waste treatment)** | Sharp objects and glass shall be contained within additional packaging or containment within a Waste Package such that they could reasonably be expected to remain contained during routine mechanical handling of the Waste Package and in the event of a rupture of the Waste Package during Supercompaction<br><br>Waste shall not contain heavy gauge metal, such as steelwork, or other items which could reasonably be expected to offer a significant and / or non-uniform axial resistance during Supercompaction.<br><br>Waste capable of generating powder or dust shall be contained in a breathable polycotton sack such that air can escape through the fabric but the powder or dust is retained during Supercompaction.<br><br>The quantity of Reassertable Waste (rubber boots, gloves, plastic sheeting etc.) in each drum must not exceed 30% by volume. | Waste shall not contain any Free Liquid or liquids with flashpoint less than 21 °C, absorbed on solid materials and, in all instances, waste shall not release more than 1 % of liquid by volume during Supercompaction.<br>Any non aqueous content of any liquid in the waste shall be conditioned, using a method approved in advance by LLW Repository Ltd, so that the volume of liquid that will be released during Supercompaction does not exceed 0.05% of the volume of the waste. | | Any drums that exceed 300 kg must be clearly identified on the Waste Consignment Information Form |