Deliverable 9.4: Overview of existing work on categorization/classification of RWs in participating states

Work Package 9 “ROUTES”

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Executive Summary

This report provides a broad overview of approaches of the participating countries to RW classification and categorization, as well as analysis challenging waste streams specific to each country.

The compilation and analysis provided herein is based on the analysis of responses to the ROUTES questionnaire, developed by ROUTES WP Board (task leaders and co-task leaders). This questionnaire was sent to all EURAD participants. It should be reminded that one of the ROUTES objective is to highlight common R&D needs for a better management of challenging wastes. Therefore, EURAD participants were not obliged to answer this questionnaire if they did not identify any difficulty that might need some future R&D programmes. Instead, EURAD participants were invited to respond if they saw an interest in sharing particular experiences that could lead to common research programmes in the future. In this context, 21 countries decided to provide answers to the Questionnaire regarding their approaches to RW classification and characterization and the challenging waste they have identified. Organisations from the same country who are participating in ROUTES were asked to collaborate to produce a single national response to this questionnaire. An exchange meeting took place in March 2020 in Athens. After that additional reviews and updates of the answers from some countries in the questionnaire were done. The results and outputs of this work are compiled in this report.

The report contains a summary of IAEA approaches to radioactive waste classification and characterization, analysis of responses to the questionnaire with regard to classification and characterization, and a summary of challenging waste from each country with reasons for why this waste is challenging. There is also provided information on available, constructed and planned disposal facilities in participating countries.

The report analyses the distinctions between classification and characterization, basing on IAEA approaches. In particular, categorization is defined by IAEA as “a method for grouping individual or combined waste streams based on the waste’s point of origin, physical state, type, properties, and process options. At the same time, IAEA approach to classification is based primarily on considerations of long term safety, and thus, by implication, disposal of the waste.

According to the responses obtained, there is no completely unified approach for RW classification in the participating countries. Various countries apply different types of RW classification, and sometimes several types of classification are used simultaneously in the same country. The IAEA GSG-1 approach to classification is somehow applied in the vast majority of participating countries. It should be mentioned that the classes “low level waste” and “intermediate level waste” do not always have the same meaning as in IAEA GSG-1, i.e. future disposal in near-surface disposal facilities and disposal facilities at intermediate depth, respectively. In many participating countries, low and intermediate level waste are combined as one class (LILW), which, in turn, is often subdivided into short-lived and long-lived RW. Generally, short-lived LILW could be associated with LLW within the meaning of IAEA GSG-1, whereas long-lived LILW could be associated with ILW within the meaning of IAEA GSG-1. However, such an interpretation is correct only in case that division of LILW into short-lived and long-lived is explicitly linked to the disposal route of this waste. This issue has not been clarified in many responses to the questionnaire.

Regarding categorization, less information is available from the responses to the questionnaire. At the ROUTES WP meeting in Athens, it was mentioned by many participants that different countries have a different understanding of RW categorization. The most comprehensive approach was presented by Belgium, which divides RW into unconditioned and conditioned, and then into respective subcategories. This approach could serve as an example of good practice for other participating countries and it is particularly detailed within this report.

Regarding challenging waste, the preliminary analysis made in this report on the nature and the reasons why some wastes are considered to be challenging, country by country, will be helpful for starting the further work in subtask 2.2.

In conclusion, this report sets the scene detailing what is at stake within each Member State, whether in terms of RW categorisation, characterisation and management of challenging wastes. All these elements will feed into ROUTES subtask 2.2, which will further detail the different approaches implemented to manage challenging wastes, as well as the potential needs to improve the management routes.

Table of content

List of figures

List of Tables

Glossary

No specific glossary has been developed for the purpose of this deliverable.

1. Introduction

Waste management routes in Europe from cradle to grave (ROUTES) work package (WP) is one of the two Strategic Studies WPs of the EURAD programme. The objectives of ROUTES are to:

- Provide an opportunity to share experience and knowledge on waste management routes between interested organisations (from different countries, with programmes at different stages of development, 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 (cradle to grave), including the management routes of legacy and historical waste, considering interdependencies between the routes.

- Describe and compare the different approaches to characterisation, treatment and conditioning and to long-term waste management routes, and identify opportunities for collaboration between Member States (MS).

The ROUTES WP is divided in seven tasks, with Task 1 being devoted to the Work Package management and coordination. There are 5 tasks (Task 2 to Task 6) which address the different technical topics of RWM from the generation to final disposal:

- Task 2: Identify challenging waste streams

- Task 3: Describe/compare characterisation approaches

- Task 4: Identify WAC used in MS

- Task 5: Solutions for small amounts of wastes

- Task 6: Shared solutions for MS

- Task 7 is devoted to interaction with Civil Society

The objectives of Task 2 are:

- To identify challenging wastes and related difficult issues to be collaboratively tackled within the Joint Programme,

- To map and share understanding at EU level of the practical issues on waste management routes, taking into account specific issues relating to challenging wastes and small inventory programmes.

ANDRA from France (Virginie Wasselin) and SSTC NRS from Ukraine (Oleksii Tokarevskyi) coordinate task 2. It will last from Month 1 of EURAD (June 2019) to Month 48 (May 2023). The activities are divided in two subtasks:

- Subtask 2.1 – Collection and analysis of existing work on categorization and classification of radioactive waste with regard to disposal options, identification of waste for which there is not yet a complete management plan in each Member State, and identification of waste management routes for pre-disposal steps. (Month 1 (June 2019) - Month 24 (May 2021)). The overview of existing work on categorization/classification of RWs in participating states is compiled in the present deliverable 9.4.

- Subtask 2.2 - Understanding at EU level of the practical issues on RWM routes for challenging waste. (Month 13 (July 2020) - Month 48 (May 2023)). The results and outputs of Task 2.2 will be compiled in a final reports D9.5 and D9.6.

2. Work methodology

The objectives of subtask 2.1 are to:

- Provide an up-to-date overview on radioactive waste categorization / classification based on contributions from the participants (collection and synthesis of answers to a questionnaire).
- Share experience and knowledge on pre-disposal steps, describe and compare the different approaches, define R&D needs and identify opportunities of collaboration.
- Describe particular problems to be solved for challenging wastes, relating to their pre-disposal steps and in view of their disposal.
- Establish an accurate and consistent list of challenging wastes in terms of their categorization as well as their management route.

To this end, the ROUTES WP Board (Task leaders and co-task leaders) developed a questionnaire. Responses to this questionnaire constitute a key input to the tasks of ROUTES WP. These responses have also feed discussions during the ROUTES workshops. This questionnaire is organised in six topics covering the activities addressed in the different tasks:

- General information
- Waste acceptance criteria
- Inventory of challenging waste and management routes
- Characterization
- Management strategy and R&D programmes
- Shared solutions for waste management

The questions, answers to which were mainly used for preparation of this report, are the following:

- **Q1 - National waste classification/categorisation scheme**
  - Do you have a classification/categorisation scheme for radioactive waste in your country? If so, could you provide it?
- **Q2 - Waste Inventory**
  - Do you have a national inventory of the waste? If so, is it available? Is it public?
  - Does the national inventory consider the future occurrence of radioactive waste? If so, which time span does this estimation cover?
  - Does the national inventory include waste resulting from decommissioning of nuclear installations?
- **Q3- About disposal facilities**
  - Is there any disposal facility already in operation in your country? If so, please provide information about the type of disposal (surface, near surface..) and the waste disposed (type, volume)
  - Do you have any other planned disposal facility? If so, provide the kind (near surface, deep geological…) of disposal and their link with the classification scheme.

- **Q11- Challenging waste**
  - Please specify which waste from the list (e.g., sludge, organic waste, ion exchange resin, bituminized waste, graphite waste, uranium/radium/thorium bearing waste, decommissioning waste, particular spent fuel, disused radioactive sealed sources, waste containing reactive, waste containing chemotoxic material) is present in your country and provide, if available, information about it ;
- **Q12 - Reasons for considering challenging waste**
  - Which are the reasons why those wastes are considered as challenging?
- **Q13 - Challenging waste and Uncertainties**
  - Which are the uncertainties associated with the waste stream?

Answers to these questions give the possibility to clarify the current situation with RW classification and characterization. A baseline of work presenting the classification and categorisation scheme for each participating country was conducted with the specific objective of offering the opportunity to Beneficiaries to identify and be aware of commonalities and differences as a basis for the future work. This has proved crucial in the analysis of the inventory of challenging waste.

Nevertheless, ROUTES WP is not intended to replace National Policies and programmes and initiatives of the different Agencies (EC, IAEA, NEA) devoted to the development of methodologies that would ensure consistency of inventories data. The ROUTES questionnaire was sent to all EURAD participants. As one of the ROUTES objective is to highlight common R&D needs for a better management of challenging wastes, EURAD participants were not obliged to answer this questionnaire if they did not identify any difficulty that might need some future R&D programmes. Instead, EURAD participants were invited to respond if they saw an interest in sharing particular experiences that could lead to common research programmes in the future. In this context twenty-one countries through their mandated actors in EURAD have provided answers to the questionnaire regarding their approaches to RW classification and characterization and the challenging waste they have identified. Organisations from the same country who are participating in ROUTES wereasked to collaborate to produce a single national response to this questionnaire.

An exchange meeting took place in March in Athens. The results and outputs of Task 2.1 are compiled in this report D9.4.

The aim of this report is to compile the information gathered through the analysis of the answers to the questionnaire, and the work done during the exchange meeting. This report also gives due consideration that some countries have refined and updated relevant information from the questionnaire. This updated information regarding classification, categorization and challenging waste is also addressed in the report.

The report also contains an overview of IAEA approaches to radioactive waste classification and categorization, as well as application of these approaches to analysis of the responses to the questionnaire.

3. Brief overview of IAEA approaches to categorization and classification of RW

3.1 IAEA approach to classification

Issues of radioactive waste (RW) classification are addressed in the IAEA document "Classification of Radioactive Waste. General Safety Guide No. GSG-1" (GSG-1). The objective of this Safety Guide is to set out a general scheme for classifying radioactive waste that is based primarily on considerations of long term safety, and thus, by implication, disposal of the waste.

The GSG-1 Safety Guide "*provides guidance on the classification of the whole range of radioactive waste: from spent nuclear fuel, when it is considered radioactive waste, to waste having such low levels of activity concentration that it is not required to be managed or regulated as radioactive waste. This Safety Guide covers disused sealed sources, when they are considered waste, and waste containing radionuclides of natural origin. The recommendations in [the GSG] Safety Guide are applicable to waste arising from all origins, including waste arising from facilities and activities, waste arising from existing situations and waste that may arise from accidents*".

The Safety Guide identifies the conceptual boundaries between different classes of waste and provides guidance on their definition on the basis of long term safety considerations.

Various schemes have evolved for classifying radioactive waste according to the physical, chemical and radiological properties that are of relevance to particular facilities or circumstances in which radioactive waste is managed. The classification systems for radioactive waste in use across the European Union varies widely in approach and application. Member States generally follow approaches and methods with a level of detail and complexity adapted to the country challenges. Inventories are generally the results of regular data collection from radioactive waste producers and schemes for the classification of radioactive waste may be developed on different basis and for purposes. Some are used purely for communication purposes, while others are dictated by the operational or long-term safety the disposal route, the availability of management or disposal facilities or the source of generation of the waste.

These schemes have, indeed, led to a variety of terminologies, which may differ from country to country and even between facilities in the same country. In some instances, this has given rise to difficulties in establishing consistent and coherent national waste management policies and implementing strategies, and can lead to less than optimal levels of safety. It also makes communication on waste management practices difficult nationally and internationally, particularly in the context of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (Joint Convention). Comparison of data published in the scientific literature is not straightforward, and difficulties can arise in trying to understand waste management programmes and practices both within and between states.

In the (GSG-1), consideration is given "*primarily to the long-term safety of waste management, since this is overriding in most cases involving its extended storage and disposal. It is reasonable to use disposal as a basis for a classification scheme in order to maintain compatibility and coherence through the different stages of waste management. This approach does not preclude the consideration of other aspects, such as occupational safety, that are pertinent in operational waste management.*

A clear distinction has to be made between a classification scheme and a set of regulatory limits. The purpose of classification is to ensure that waste is managed in a safe and economic manner within the framework of a national strategy and to facilitate communication, while the purpose of regulatory limitation is to ensure the safety of each licensed facility and activity. While a waste classification scheme may be useful for generic safety considerations, it is not a substitute for specific safety assessments performed for an actual facility and involving good characterization of radioactive waste.

Classification of radioactive waste may be helpful in planning a disposal facility and at any stage between the generation of raw waste and its disposal.

It will help:

— At the conceptual level:

• In devising waste management strategies;

• In planning and designing waste management facilities;

• In assigning radioactive waste to a particular conditioning technique or disposal facility.

— At the legal and regulatory level:

• In the development of legislation;

• In the establishment of regulatory requirements and criteria.

— At the operational level:

• By defining operational activities and in organizing the work to be undertaken with the waste;

• By providing a broad indication of the potential hazards associated with the various types of radioactive waste;

• By facilitating record keeping.

— For communication:

• By providing terms or acronyms that are widely understood in order to improve communication among all parties with an interest in radioactive waste management, including generators and managers of radioactive waste, regulators and the public.

To satisfy all these purposes, an ideal radioactive waste classification scheme should meet a number of objectives, namely:

- *Cover the full range of radioactive waste types;*
- *Be of use at all steps of radioactive waste management and be able to address the interdependences between them;*
- *Relate radioactive waste classes to the associated potential hazards for both present and future generations;*
- *Be sufficiently flexible to serve specific needs;*
- *Be straightforward and easy to understand;*
- *Be accepted as a common basis for characterizing waste by all parties, including regulators, operators and other interested parties;*
- *Be as widely applicable as possible.*

It is clearly not possible to develop a unique classification scheme satisfying fully all these objectives simultaneously. For instance, a classification scheme cannot at the same time be universally applicable and still reflect the finer details of all the steps of radioactive waste management. Compromise will be needed to ensure simplicity, flexibility and broad applicability of the scheme.

In developing a classification scheme:

— The definition of waste classes should be developed on a sound technical basis, should be clear and should be easily understandable;

— The general nature and applicability of the classification scheme should be clearly understandable;

— The number of classes should be such as to achieve a balance between the desired differentiation among waste types and the ease of handling of the classification scheme.

Six classes of waste are derived and used as the basis for the IAEA classification scheme (Fig.1):

(1) Exempt waste (EW): Waste that meets the criteria for clearance, exemption or exclusion from regulatory control for radiation protection purposes.

(2) Very short lived waste (VSLW): Waste that can be stored for decay over a limited period of up to a few years and subsequently cleared from regulatory control according to arrangements approved by the regulatory body, for uncontrolled disposal, use or discharge. This class includes waste containing primarily radionuclides with very short half-lives often used for research and medical purposes.

(3) Very low level waste (VLLW): Waste that does not necessarily meet the criteria of EW, but that does not need a high level of containment and isolation and, therefore, is suitable for disposal in near surface landfill type facilities with limited regulatory control. Such landfill type facilities may also contain other hazardous waste. Typical waste in this class includes soil and rubble with low levels of activity concentration. Concentrations of longer lived radionuclides in VLLW are generally very limited.

(4) Low level waste (LLW): Waste that is above clearance levels, but with limited amounts of long lived radionuclides. Such waste requires robust isolation and containment for periods of up to a few hundred years and is suitable for disposal in engineered near surface facilities. This class covers a very broad range of waste. LLW may include short lived radionuclides at higher levels of activity concentration, and also long lived radionuclides, but only at relatively low levels of activity concentration.

(5) Intermediate level waste (ILW): Waste that, because of its content, particularly of long lived radionuclides, requires a greater degree of containment and isolation than that provided by near surface disposal. However, ILW needs no provision, or only limited provision, for heat dissipation during its storage and disposal. ILW may contain long lived radionuclides, in particular, alpha emitting radionuclides that will not decay to a level of activity concentration acceptable for near surface disposal during the time for which institutional controls can be relied upon. Therefore, waste in this class requires disposal at greater depths, of the order of tens of metres to a few hundred metres.

(6) High level waste (HLW): Waste with levels of activity concentration high enough to generate significant quantities of heat by the radioactive decay process or waste with large amounts of long lived radionuclides that need to be considered in the design of a disposal facility for such waste. Disposal in deep, stable geological formations usually several hundred metres or more below the surface is the generally recognized option for disposal of HLW.

Quantitative values of allowable activity content for each significant radionuclide will be specified on the basis of safety assessments for individual disposal sites (which is outside the scope of (GSG-1).

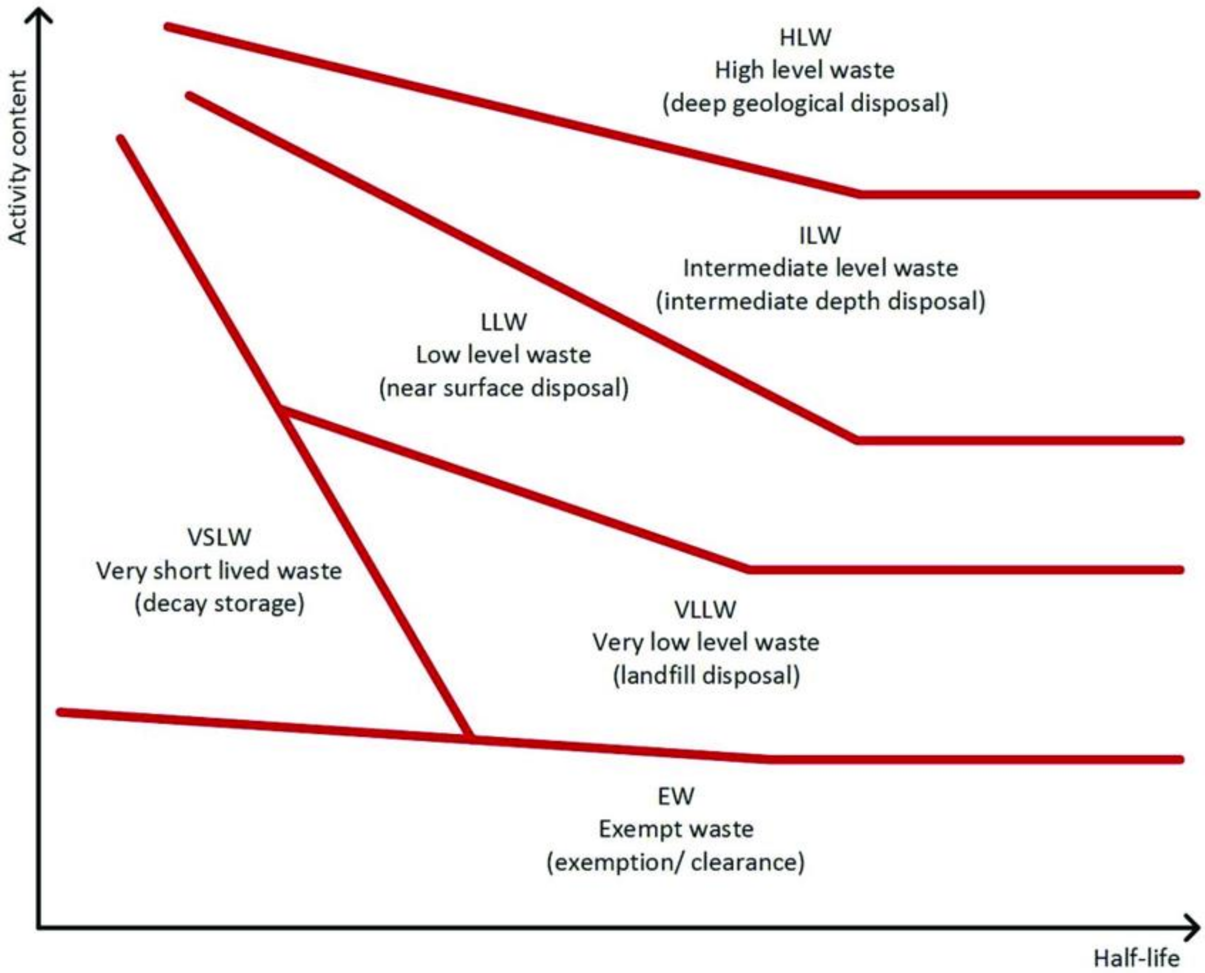

Figure 1 : Conceptual illustration of the IAEA waste classification scheme

3.2 IAEA approach to categorization (IAEA TECDOC 1538)

According to IAEA document "IAEA-TECDOC-1538. Categorizing Radioactive Waste" (TECDOC 1538), *"classifying wastes based solely on radioactivity concentrations and species content is plausible; however it has been proven that this approach is not viable for all waste types during every phase of the waste management process. In contrast, "categorization" of waste so as to include such factors as origin, physical state, type of waste, properties, and process options provides the basis for an improved, consistent approach".*

(TECDOC-1538) provides a simple categorization approach, which is based on the two primary operational waste categories listed below:

1. unconditioned, as-generated waste; and
2. conditioned waste.

Each primary category has five components or "subcategories," which form the basis for the definition of categorization. Accordingly, categorization is defined by IAEA as "a method for grouping individual or combined waste streams based on the waste's point of origin, physical state, type, properties, and process options." The bases for this definition are outlined in the following five subcategories below:

- Point of origin (source of the as-generated raw waste);
- Physical state (solid, liquid, gaseous);
- Type (resin, sludges, metal, combustible, compactable, etc.);

- Properties (radiological, physical, chemical, biological);
- Process options (pre-treatment, treatment, conditioning).

Additional details for each of these subcategories are provided in (TECDOC-1538). As stated in (TECDOC-1538), "*this categorization approach supports safe and cost effective segregation and management of waste prior to and throughout treatment, conditioning and disposition*".

TECDOC-1538 recommends that operational waste categorization programme be implemented prior to generation of any waste, because it is critical for ensuring the future, long-term success of the programme. The categorization process should be revised as the waste management programme evolves. At that, some countries with advanced programmes may have established protocol and implemented practices for operational waste categorization.

As stated in (TECDOC-1538), *"A comprehensive, standardized operational waste categorization programme provides a platform for accurately assessing management options, including, but not limited to:*

– Waste segregation;

– Preliminary waste characterization and classification;

– Selection of cost effective, regulatory compliant waste treatment and conditioning options;

– Mobile processing technology selection;

– Processing resource sharing with other facilities and/or countries;

– Validation of compliance with final repository waste acceptance criteria;

– Infrastructure investment sharing between facilities and/or countries with similar challenges and close proximity;

– Pursuit of alternative disposal options for materials of low radiological risk (e.g. in facilities that do not maintain a radioactive materials license including, but not limited to industrial or hazardous waste landfills).

Additionally, categorization of radioactive waste can be helpful at any stage between the point of generation and subsequent handling, transport, processing, storage, and disposal:

– At the conceptual level in:

• devising waste management strategies;

• planning and designing waste management facilities;

• routing radioactive waste for processing, storage and disposal;

– At the operational level by:

• defining operational activities and in organizing the sequence of activities;

• giving a broad indication of the potential hazards involved with the various types of radioactive waste;

• facilitating record keeping;

– With communication:

• by providing universally recognized terminology that improves communication between countries, the public, regulators, and finally generators and managers of radioactive waste programmes".

4. Overview of responses to the questionnaire

Twenty-one countries have provided answers to the questionnaire regarding their approaches to RW classification and characterization. The answers show considerable variation in approaches and level of detail. Below, there is a summary of information presented by EURAD participants.

4.1 Approaches to RW classification

In this subsection, answers from different EURAD participating countries related to waste classification are presented.

As mentioned in Section 3, there is no unified approach for RW classification. Various countries apply different types of RW classification; indeed, several types of classification are sometimes used simultaneously in the same country. A summary of approaches to RW classification by country is presented in Table 1. The following criteria for classification can generally be distinguished:

- level of activity
- half-life
- heat generation
- disposal route

Some countries (e.g. Austria, Denmark) have not implemented their own classification scheme, but declare that they are using IAEA approach, stated in GSG-1 (see Section 3). At that, it should be mentioned that IAEA GSG-1 is not a prescriptive document but provides recommendations which are applicable to waste arising from all origins and can be useful for all participating countries.

In Table 2, the information from EURAD participating countries regarding RW classification related to RW disposal route, recommended by IAEA GSG-1, is summarized.

This approach to classification is applied to some extent in the vast majority of participating countries, but aspects of some national waste classification schemes deviate from the IAEA approach. Therefore, the classes “low level waste” and “intermediate level waste” do not always mean the same as in (GSG-1), i.e. future disposal in near-surface disposal facilities and disposal facilities at intermediate depth, respectively.

In many participating countries (e.g. Bulgaria, Lithuania, Netherlands), low and intermediate level waste do not exist as separate classes and are combined as one class (LILW), which, in turn, can be subdivided into short-lived and long-lived RW. Generally, short-lived LILW could be associated with LLW within the meaning of (GSG-1), whereas long-lived LILW could be associated with ILW within the meaning of (GSG-1). It seems that this interpretation is directly linked with the potential disposal route of those wastes, even if it has not been mentioned explicitly within the different questionnaire responses..

For illustrative purposes, Table 3 presents the information regarding available and planned disposal facilities in the participating countries.

As one can see from Table 3, the creation of deep geological repositories is planned in the vast majority of participating countries. The same is applicable for the disposal facilities for LLW (sometimes such facility is called “surface”, sometimes – “near-surface” – this is rather an issue of terminology, as opposed to a clear distinction in the features of the disposal facilities, as discussed further below).

At the same time, only few countries (Sweden, France, Ukraine) are planning to create a disposal facility at intermediate depth for ILW.

With regard to very low-level RW, only a few countries have dedicated disposal facilities (in particular, Slovakia, Spain, UK) or are planning to create them (Hungary, Romania). Sometimes, these facilities belong to landfill type, sometimes – to surface type.

The distinction between landfill, surface and near-surface disposal facilities in Table 3 is not clear-cut – it appears to be a combination of disposal depth and the level of engineering applied in the facility design. It should be mentioned that national facilities are assigned to these columns based on the conventions and terminology used in each country's response to the questionnaire. At that, (GSG-1) defines "near-surface landfill type facilities" as a suitable disposal route for VLLW, and "engineered near surface facilities" as a suitable disposal route for LLW. In view of this, there is a degree of overlap between landfill, surface and near-surface disposal facilities. Table 3 provides an overview of the variety of approaches to the disposal routes implemented in the Member States that have decided to respond to the ROUTES questionnaire (cf. section 2).

Table 1: Approaches to RW classification by country

	Country	Level of activity	Half-life	Heat Generation	Type of disposal facility	IAEA approach (GSG-1)
1.	Austria	+	+	No heat generating RW		+
2.	Belgium		+	+	+	
3.	Bulgaria	+	+	+	+	
4.	Czech Republic	+ (indirectly, (disposal facility specific))	+ (temporary RW)	+	+ (indirectly)	+ (indirectly, (disposal facility specific))
5.	Cyprus					+
6.	Denmark					+
7.	France	+	+		+ (indirectly)	
8.	Germany			+		
9.	Greece	+	+	No heat-generating RW	+	+
10.	Hungary	+	+			
11.	Lithuania	+ (dose rate)	+		+	
12.	Netherlands	+	+			
13.	Poland	+	+	No heat-generating RW		
14.	Portugal	+	+			+
15.	Romania	+	+		+	
16.	Slovakia	+	+		+	

	Country	Level of activity	Half-life	Heat Generation	Type of disposal facility	IAEA approach (GSG-1)
17.	Slovenia	+	+	+		
18.	Sweden	+ (dose rate)	+	+	+	
19.	Spain	+	+	+ (Waste Agency (ENRESA) classification)	+	+
20.	Ukraine	+	+	+	+	
21.	UK	+ (for non-rad/LLW and LLW/ILW boundaries)		+ (for ILW/HLW boundary)	+ (for LAW/HAW boundary and for disposal of VLLW)	

Table 2: RW classification by disposal route according to GSG-1 by country

	Country	Exempt	Very short-lived (transition,...)	Very low level	Low level	Intermediate level	High level	Criterion for division
1.	Austria	+	+		+ (LILW)	+ (LILW)	- (no HLW in Austria)	Specific activity. LILW are subdivided into short-lived and long-lived
2.	Belgium			- (Belongs to Category A, as no specific disposal option is envisaged)	+ (Category A)	+ (Category B)	+ (Category C)	Type of disposal
3.	Bulgaria	+	+ (very short-lived waste)	+	+ (LILW)	+ (LILW)	+	Depending on activity, needs of measures for radiation protection, reliable isolation and retention. Heat generation for HLW. LILW are subdivided into short-lived and long-lived
4.	Czech Republic	+	+	+	+	+	+	Origin and type of waste, total and specific/volume activity - radionuclide specific, disposal site specific.
5.	Cyprus							No detailed information provided, IAEA classification is applied
6.	Denmark							All waste planned to be disposed of in a deep geological repository
7.	France			+	+	+	+	Specific activity. There is no direct relationship between RW type and disposal route.

	Country	Exempt	Very short-lived (transition,…)	Very low level	Low level	Intermediate level	High level	Criterion for division
8.	Germany							All waste are planned to be disposed of in deep geological repositories
9.	Greece		+ (very short-lived waste)	+	+	+	- (No HLW in Greece)	RW in Greece is classified as VSLW, VLLW, LLW and (in limited quantities) ILW, based on the IAEA methodology described in GSG-1. The distinction between very short lived and long lived RW is based on the half-lives of 100 days and 30 years, respectively.
10.	Hungary			+	+	+	+	Specific activity Heat generation for HLW.
11.	Lithuania	+		+	+	+	+ (SNF)	Dose rate. LILW are subdivided into short-lived and long-lived
12.	Netherlands	+			+ (LILW)	+ (LILW)	+	Not clear from the answer. Short-lived waste as separate class
13.	Poland		+		+ (≤10^8 Bq for DSRS)	+ (10^8 – 10^{12} Bq for DSRS)	+ (>10^{12} Bq for DSRS)	Activity level

	Country	Exempt	Very short-lived (transition,...)	Very low level	Low level	Intermediate level	High level	Criterion for division
14.	Portugal		+	+	+	+		According to the questionnaire of PT submitted (April, 7th 2020), in Q1, PT has a classification of radwaste in the National Plan for the Management of Spent Fuel and Radioactive Waste (VLLW, LLW, ILW). This classification is based on the activity and half-life. PT follows IAEA GSG-1 and the wastes produced in the Country.
15.	Romania	+	+	+	+ (LILW - SL)	+ (LILW - LL)	+ (SNF)	Specific activity LILW are subdivided into short-lived (to be disposed in near-surface disposal facility) and long-lived (to be geological disposed of)
16.	Slovakia		+	+	+	+	+	Specific activity of long-lived RW only (?)
17.	Slovenia		+	+	+ (LILW)	+ (LILW)	+	Not clear from the answer. Heat generation for HLW. LILW are subdivided into short-lived and long-lived The transition RW are just stored on site and then cleared, so no disposal route is foreseen.
18.	Spain	+ (from declassification process)		+ (subdivided into short-lived and long-lived)	+ LILW (subdivided into short-lived and long-lived)	+ LILW (subdivided into short-lived and long-lived)	+ (SNF & HLW)	VLLW and LILW are subdivided into short-lived and long-lived EW coming from declassification processes

	Country	Exempt	Very short-lived (transition,...)	Very low level	Low level	Intermediate level	High level	Criterion for division
19.	Sweden	+		+	+	+	+ (SNF)	Dose rate. Heat generation for HLW. LILW are subdivided into short-lived and long-lived
20.	Ukraine			+	+	+	+	Disposal type, heat generation for HLW
21.	UK	+		+	+	+	+	Out-of-scope waste (non-radioactive): does not exceed radionuclide-specific activity values defined by Euratom Disposal route for VLLW (based on activity) Activity for LLW and ILW Heat generation for HLW The UK is increasingly moving towards a more risk-based approach to radioactive waste management that enables improved management of wastes at the boundaries between existing classifications.

Table 3: Available disposal facilities by country

	Country	Landfill	Surface	Near-Surface	Intermediate Depth	Deep Geological Repository	Comments
1.	Austria						Type not decided yet, there are plans to create the disposal facility by 2045.
2.	Belgium		For waste of Category A (SL-LILW) License: 2022 Operation: 2025			Until now, there is no official decision (Royal Decree) that confirms Belgium will go for a DGR, so nothing is decided at the moment, even on a principle level.	
3.	Bulgaria			SL-LILW Under construction		Planned	
4.	Czech Republic	Exempt waste, limited volume and activity	NPP Waste, limited volume of institutional waste	Institutional waste, containing natural/artificial radionuclides		All RW, not acceptable for surface and near surface disposal.	
5.	Cyprus						No facilities planned, according to the Questionnaire
6.	Denmark					Planned, not later than 2073 All RW, may be except for NORM	

7.	France		CIRES Facility for VLLW (Aube department) CSA Facility for SL-LILW (Aube department) CSM Facility for SL-LILW (Manche department) – closed	Facility for LLW-LL (Soulaines region) Stage of site selection		Cigéo disposal facility (Meuse/Haute Marne) Operation: about 2030	
8.	Germany					Two facilities: 1. Konrad for RW with negligible heat generation (licensed, under construction) Operation: 2027 2. Other facility for heat-generating RW (on-site, interim-storage). Site to be selected by 2031 Operation: about 2050	
9.	Greece			One facility which will include the combination of i) engineered near surface disposal, ii) surface trench disposal.			According to the NatPRo: The technical choice determined by the RWMO (EEDRA) includes the combination in one installation of i) engineered near surface disposal, ii) surface trench disposal. Borehole solution is not excluded, in case its necessity arises, but it is not a preferred solution

10.	Hungary	Planned	Radon-type facility for institutional RW	Underground facility for LILW from NPP operation and decommissioning		Planned by 2064	
11.	Lithuania	Operation will start in 2021		Construction – tender procedures. Operation: planned for 2024		Planned by 2066	Bituminized LRW storage facility to be transformed to disposal facility
12.	Netherlands	Two facilities for NORM waste				Planned by 2130	
13.	Poland		KSOP facility (intended for disposal of gamma and beta bearing waste and for temporary storage of alpha-bearing LLW and ILW)				Other disposal facility is planned, but the type has not been decided yet.
14.	Portugal						The National Plan refers disposal but does not indicate specific routes.
15.	Romania		May be, separate facility for VLLW will be considered.	National Repository Baita Bihor for institutional RW Disposal facility for NPP RW (SL-LILW) Operation: 2028		Planned by 2055	
16.	Slovakia	Facility for VLLW (surface type) Extension is planned	Facility for LLW Extension is planned			Planned for SNF and ILW	

17.	Slovenia	Waste from uranium mining (Jazbec - closed and Borst – still under remediation due to landslide activation)		Near-surface facility for SL-LILW Licensing stage (construction)		Planned by 2065. SNF and HLW May be regional or multinational – not decided yet	
18.	Spain		Trench-type facility at El Cabril for VLLW (Landfill similar to the repository for toxic and hazardous wastes)	Near-surface facility at El Cabril for LILW		There is no date for deep geological repository for SF and HLW because the final decision has not been made yet (technically and administratively). A Centralized Temporary Storage (CTS) will be build up in the next years .	The CTS is an industrial facility designed to accommodate for 60 years the spent fuel and other high level waste in a single location. According to the Plan (GRWP), there is an estimated 12,000 m^3 of materials requiring management, most of them are spent fuel (about 20,000 fuel assemblies) and small quantities of vitrified waste (less than 70 canisters) and special waste.
19.	Sweden	Landfill facility		SL LILW shallow geological repository, extension is planned	Planned (trial operation – 2044)	Planned (trial operation – 2044)	

20.	Ukraine	Radon-type facilities, STLRW for accident Chornobyl waste, safety reassessment has to be done to decide whether RW removal is necessary	Buryakivka trench-type facility for accident waste of Chornobyl origin	ENSDF for SL-LILW 2 compartments of 22 are in operation Disposal facilities at Vector complex (SRW-1, SRW-2) for RW disposal in containers and in bulk, respectively	Option for disposal of ILW is under discussion – separate facility or codisposal with HLW	Planned (roadmap is under development)	
21.	UK	Three landfill sites for VLLW		Two facilities: LLWR in Cumbria and LLWF in Dounreay		Planned for HAW in England and Wales Stage of site selection	Scotland has a different policy that disposal of HAW should be performed in near-surface facilities located as near as possible to the site where the waste was produced.

In operation
Closed
Under construction
Planned

4.2 Approaches to RW categorization

4.2.1 Summary of answers related to RW characterization by country

Regarding categorization, less information was available from the initial responses to the questionnaire. According to (TECDOC-1538), categorization is a method for grouping individual or combined waste streams based on the waste's point of origin (source of the as-generated raw waste), physical state (liquid, gaseous, solid), type (resins, sludges, slurry, metal, combustible, compactable, etc.), properties (radiological, physical, chemical), and process options (pre-treatment, treatment, conditioning). IAEA defines two primary categories of RW – unconditioned (as-generated) RW and conditioned RW. These RW are then further divided by subcategories. At the ROUTES WP meeting in Athens, it was mentioned by many participants that different countries have a different understanding of RW categorization.

In the course of the development of this report, the information from the participants was updated based on their feedback. As one can see from Table 4, RW categorization is somehow applied in the majority of participating countries. Nevertheless, in most of the countries the management strategy is mainly defined on the basis of classification rather than categorisation. The most comprehensive approach was presented by Belgium, which divides RW into unconditioned and conditioned, and then into respective subcategories. During the ROUTES Workshop held in Athens (March 2020), participants agreed to say that Belgium has developed a comprehensive approach of RW categorization that can be considered as a good practice to be shared among all ROUTES partners and to be used as a guide implementation in the interested MS. In that sense, the particular Belgian approach is described in detail below in Section 4.2.2. Note that in other countries, some categories of RW have been implemented (e.g. solid/liquid RW, disused SRS, etc.) and they are not as completed as the Belgian one.

Short summary of answers to the questionnaire related to RW categorization is presented in Table 4. Within this table, it is worth to note that when the whole row for the country is blank, it means that answers to the questionnaire do not provide clear information about approaches RW categorization (and whether categorization is applied at all) in those countries. Once again, note that this table gather only the responses from the Member States that have decided to answer to the ROUTES questionnaire.

Table 4: Approaches to RW categorization by country

	Country	Categories	Subcategories				
		Non-conditioned / Conditioned	Point of origin	Physical state (liquid, solid, gas)	Type	Properties (radiological, chemical, physical, etc.)	Process options
1.	Austria	+		+ (s/l/g)	+ (e.g. combustible, non-combustible, DSRS, filters, smoke detectors)	+	+ (e.g supercompacted waste, homogenously cemented, waste, ecapsulated (sources and ash drums)
2.	Belgium	+		+ (s/l)	+ (e.g. organic, combustible, compatible)	+ (radiological, chemical, etc.)	+ (e.g. incineration, compaction)
3.	Bulgaria			+ (s/l)			
4.	Cyprus			+ (s/l)			
5.	Czech Republic	+	+ (institutional, NPPs origin)	+ (s/l/g)	+ (containing natural/artificial radionuclides)		+ (solidification media, e.g. bitumen, cement, geopolymer)
6.	Denmark			+	+ (e.g. waste from decom, operations, other users)		
7.	France						

8.	Germany	+	+ (decommissioning waste, legacy waste, radiation sources reprocessing wastes, SNF)	+ (s/l/g)	+ (organic/inorganic, combustible/non-combustible)	+ (chemical, physical properties)	
9.	Greece		+ (decommissioning waste, legacy waste…)	+ (s/l)	+		
10.	Hungary	+	+ (institutional radioactive waste; NPP originated radioactive waste)	+ (s/l)	+ (Compactable/ non-compactable, solidified liquid, sludge, resin)		+ (compaction, solidification)
11.	Lithuania	+		+ (s/l/g)	+ (DSRS as a separate category)		
12.	Netherlands	+	+			+	
13.	Poland			+s/l	+ (Separate criteria are established for DSRS)		
14.	Portugal	+	+ (legacy waste, radiation sources)	+ (s/l)			+ (compaction)
15.	Romania* (for operational waste)		+	+	+	+	+
16.	Slovakia						
17.	Slovenia			+ (s/l/g)	+ (organic/inorganic, combustible/non-combustible)	+ (chemical, physical properties)	
18.	Spain						

19.	Sweden						
20.	Ukraine			+ (s/l)			
21.	UK	No formal system of radioactive waste categorization is applied in the UK. The UK radioactive waste inventory (available at https://ukinventory.nda.gov.uk) records whether wastes are conditioned or unconditioned and also records details of waste characteristics including those listed as subcategories in this table. All of this information can then be interrogated as required when considering a particular radioactive waste management application.					

4.2.2 Belgian approach to categorization

First of all, the waste is divided into two categories – conditioned and non-conditioned RW.

Subcategorization of non-conditioned waste (NCW)

A subcategorization scheme of NCW is two-dimensional. The first dimension is related to the contamination risk from the waste and the second dimension the radiation risk exposure from the waste.

The categorization of NCW has a separate scheme for solid waste and one for liquid waste.

Subcategorization scheme for solid NCW

Subcategorization scheme for solid NCW in Belgium is presented below in Fig.2.

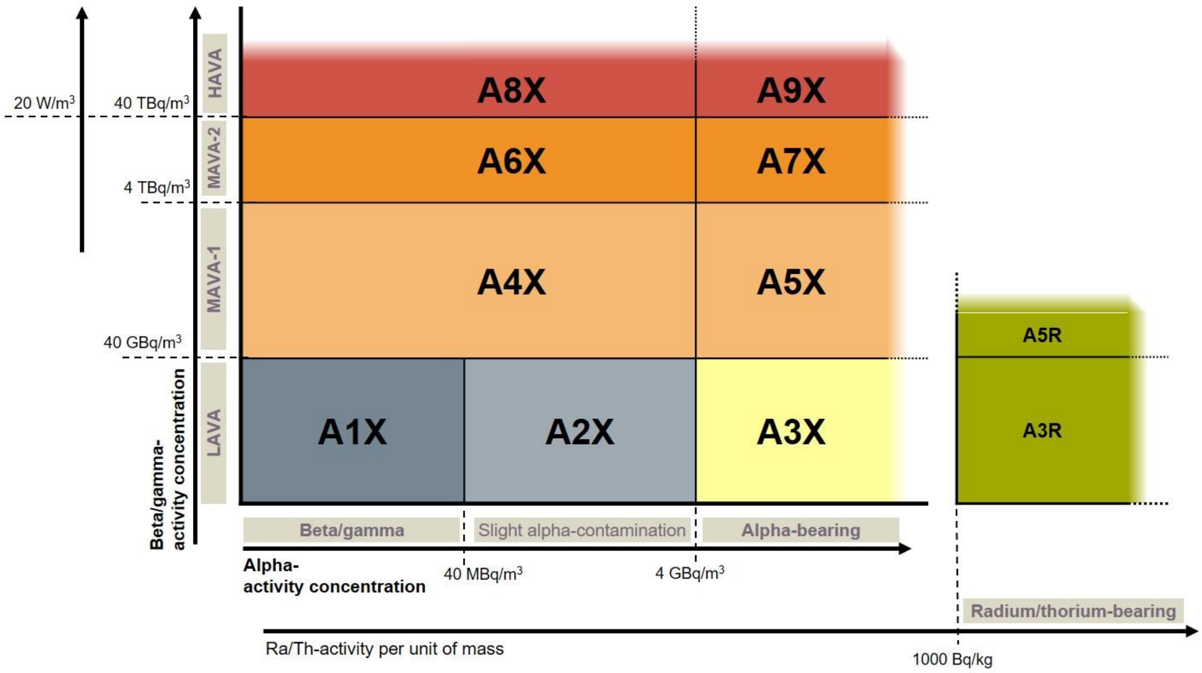

Figure 2: ONDRAF/NIRAS subcategorization scheme for solid NCW

The contamination risk from solid NCW is measured by the total activity concentration of alpha-emitters in the waste (Bq/m³). In terms of contamination risk, the scheme makes the distinction between beta/gamma waste and alpha-bearing waste; the former may contain no more than traces of alpha-emitters. Considering that alpha-emitters in the waste are generally long-lived, this dimension in the classification scheme not only addresses operational but also long-term safety.

The radiation danger from solid NCW is measured by the total activity concentration of beta/gamma-emitters in the waste (Bq/m³). In terms of radiation danger, the scheme makes the distinction between low active, (two levels of) medium active and high active solid NCW. To distinguish high active solid NCW, the thermal power density (W/m³) is also taken into consideration.

The solid NCW is classified based on whether it is beta/gamma or alpha-bearing and on its activity level and thermal power density. The solid NCW is further subdivided into classes on the basis of the possible treatment methods (i.e. incineration or other pre-treatment leading to compaction). For burnable solid waste, a very low limit is observed on the total activity concentration of alpha-emitters in the waste.

Radium/thorium-bearing solid NCW is attributed to a class separate from the scheme.

Subcategorization scheme for liquid NCW

The subcategorization scheme for liquid NCW in Belgium is presented below in Fig.3.

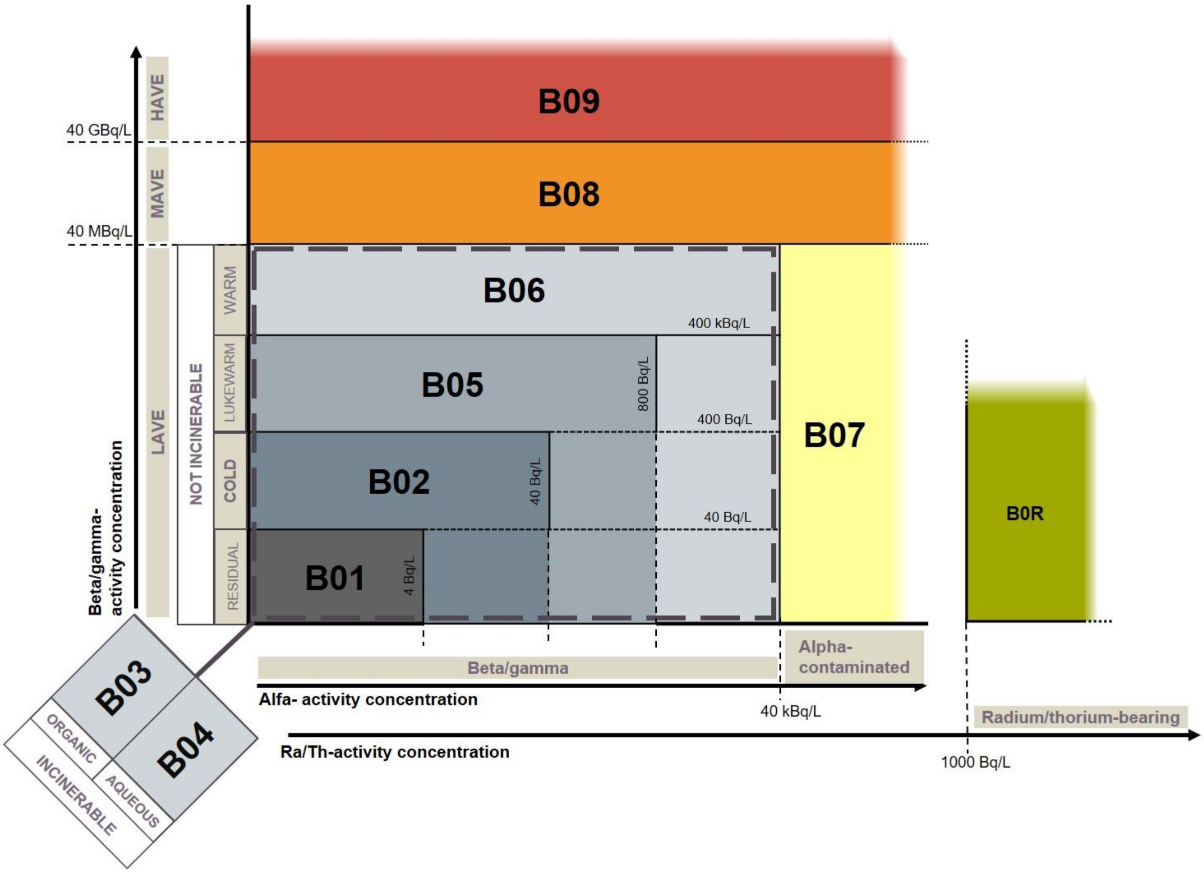

Figure 3: ONDRAF/NIRAS subcategorization scheme for liquid NCW

The classification of liquid NCW makes a distinction between heterogeneous liquid ("sludge") and homogeneous liquid ("effluent"). There exists a classification scheme for effluent only. Sludge is not further subdivided into categories.

The contamination risk from an effluent is measured by the total activity concentration of alpha-emitters in the effluent (Bq/litre). The radiation danger is measured by the total activity concentration of beta/gamma-emitters in the effluent (Bq/litre). In terms of radiation exposure risk, the scheme makes a distinction between low, medium and high active effluent.

The low active effluent is further subdivided into several categories based on the combination of the total activity concentration of alpha-emitters, the total activity concentration of beta/gamma-emitters and whether or not it is destined for incineration. The low active effluent destined for incineration is subdivided in two categories, depending on the nature of the solvent (i.e. aqueous or organic).

Radium/thorium-bearing effluent is attributed to a separate class apart from the scheme.

Categorization of conditioned waste (CW)[1]

The subcategorization scheme for CW in Belgium is presented below in Fig.4.

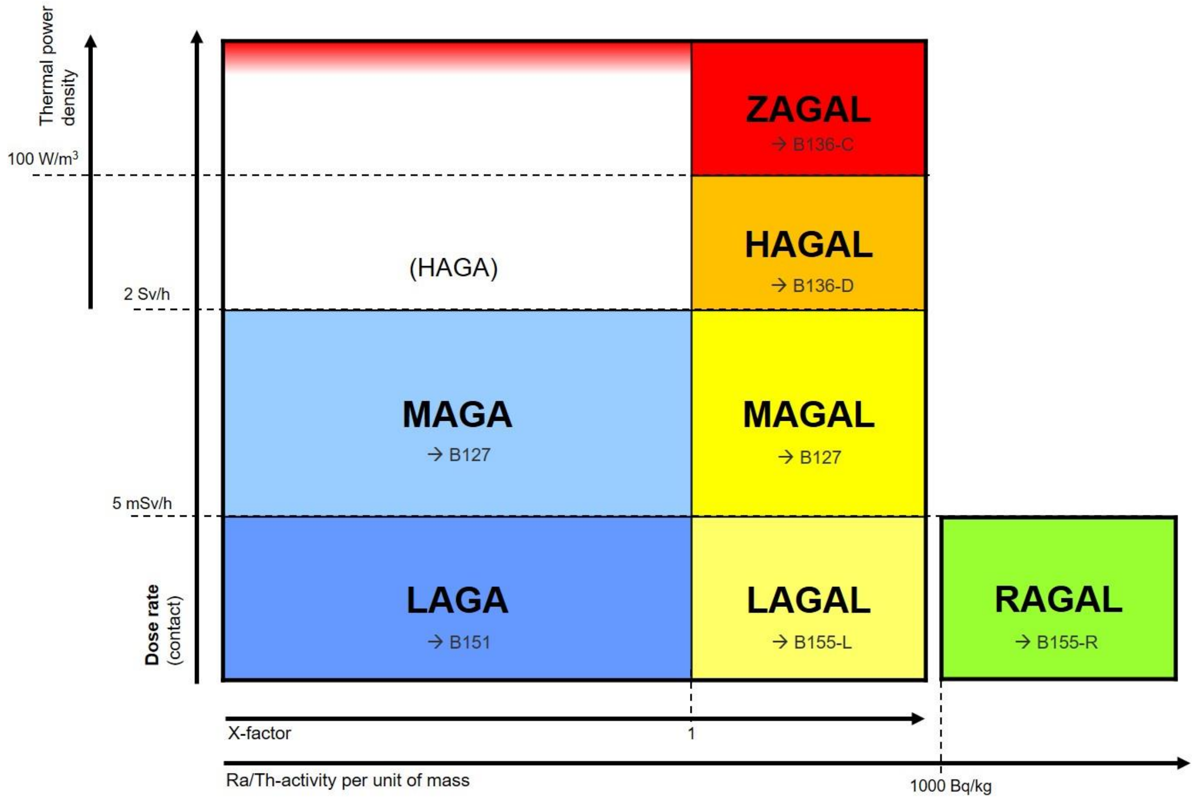

Figure 4: ONDRAF/NIRAS subcategorization scheme for CW

The subcategorization scheme of CW is two dimensional. The first dimension expresses the half-life of the radionuclides in the waste. The second dimension expresses the radiation exposure risk from the waste.

The longevity of the radionuclides in CW is measured by a dimensionless number ("X-factor"), which is the sum of the ratios of the activity concentration (Bq/m^3) of certain "critical" nuclides to their maximum limit based on the most conservative scenario of intrusion after disposal (remaining below radiological dose limits). In terms of longevity, the scheme makes the distinction between short-lived and long-lived CW; the former may not have an X-factor greater than 1.

The radiation danger from CW is measured by its dose rate (Sv/h). In terms of radiation danger, the distinction is made between low active, medium active, high active and very high active CW. To distinguish very high active CW, the thermal power density (W/m^3) is also taken into consideration.

The CW is divided into categories based on whether it is short-lived or long-lived and on its dose rate and thermal power density. This classification scheme is supplemented by categories that also take account of the origin of the CW (e.g. vitrified HLW from La Hague).

Radium/thorium-bearing CW is attributed to a category separate from the scheme.

[1] This can be called a classification or a categorization, depending on the point of view. It is a categorization in the sense that the classes are associated with a specific storage building. It is a classification in the sense that the classes can also be associated with a specific option for disposal.

RW classification in Belgium related to disposal

In terms of disposal, CW belongs to category A if it is destined for the surface repository (planned to be constructed in the municipality of Dessel). Short-lived low active and short-lived medium active CW are a priori considered to belong to category A. CW belongs to category B or C if its reference final destination is geological disposal. A characteristic of CW belonging to category C is its high thermal power density, such that this has a major impact on the design of the repository. When comparing with the classification scheme in Figure 1 of GSG-1 (see above), category A corresponds with LLW, category B corresponds with ILW and category C corresponds with HLW. Since no specific final destination is planned for VLLW, the latter is included in category A.

The Belgian approach to RW classification related to disposal route and its link to IAEA GSG-1 approach is shown in Fig.5.

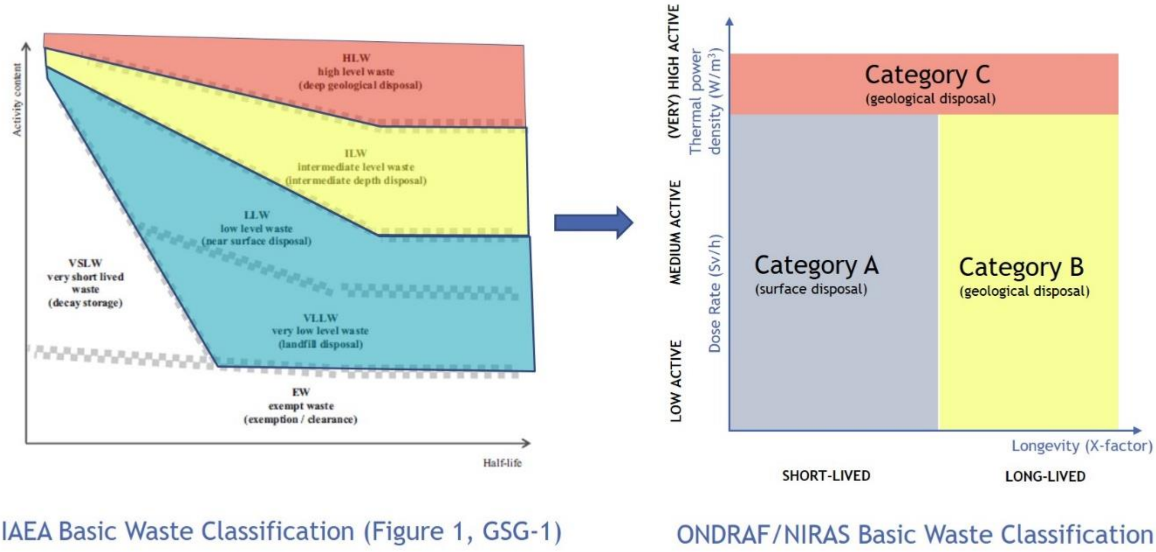

Figure 5: ONDRAF/NIRAS RW classification scheme and its relation to disposal route

5. Overview of responses to the questionnaire on challenging waste

5.1 Introduction

Challenging wastes (sometimes called problematic or no routes waste) are those for which no solutions for their safe management are currently available: one of the predisposal steps (including characterization, treatment and conditioning) is not available or the disposal strategy is not yet defined. For instance, legacy wastes are often considered as challenging waste because of the lack of knowledge on their characteristics, which prevents the definition of the route for safe management. Apart from this case, some challenging waste is still to be generated, for example waste containing organic materials for which most of the member states (MS) are still looking for a treatment/conditioning technology. This example particularly refers to THERAMIN EC project[2] ("Thermal treatment for radioactive waste minimization and hazard reduction"). This project aimed to provide improved safe long-term storage and disposal of intermediate and low level radioactive waste streams (ILW and LLW), suitable for thermal processing.

Another consideration to have in mind is the fact that a lack of sorting can lead to mixed waste. As a whole, mixed waste can be more problematic to manage, whereas if there were treated separately, an appropriate management route could be found.

5.2 Summary of challenging waste per country

This section summarizes the answers from the MS in regard to the challenging wastes they have to face. Regarding the questionnaire itself, it has to be noticed that a preliminary list of 'challenging wastes' was included. This list was drawn up during the preparatory phase of the ROUTES project on the basis of information provided by few member states. Precisely, the predefined list of challenging wastes included:

- Sludge;
- Organic Waste;
- Spent Ion exchange resins (SIERs);
- Bituminized waste;
- Graphite;
- Uranium/Radium/Thorium bearing waste;
- Decommissioning Waste (soil, rubble, etc.);
- Particular spent fuel such as metal uranium and aluminium cladding;
- Disused radioactive sealed sources;
- Waste containing reactive metals such as Aluminium, Magnesium, Zirconium, Sodium, Beryllium;
- Waste containing chemotoxic materials such as Beryllium, Mercury, Asbestos, Lead.

For sake of brevity, single responses to the questionnaire provided by each MS are compiled in a separate document. Table 5 details for each member state the different types of challenging wastes they face, based on this list and the answers to the questionnaire. Associated with this table, the pie chart presented in Figure 6 illustrates the distribution of challenging waste that member states are most confronted with.

[2] http://www.theramin-h2020.eu/

Table 5: List of challenging waste identified by Member States participating to the ROUTES project

	sludges	organic waste	spent ion exchange resin	bituminized waste	graphite	uranium/radium/thorium bearing waste	decommissioning waste	particular spent fuel	DSRS	waste containing reactive metals (Al, Mg...)	waste containing chemotoxic (asbestos, beryllium, mercury...)
Austria	x	x	x		x	x	x		x	x	x
Belgium		x	x	x	x	x	x	x	x	x	
Bulgaria	x		x				x		x		
Cyprus						x			x		
Czech Republic											
Denmark	x	x	x	x	x	x	x	x	x	x	x
France	x	x	x	x	x	x	x	x	x	x	x
Germany					x						x
Greece	x	x	x		x	x	x		x	x	x
Hungary	x	x							x	x	x
Lithuania				x	x		x		x		x
Netherlands			x		x			x		x	x
Poland		x			x	x	x		x	x	
Portugal		x	x		x	x	x		x	x	
Romania			x		x	x	x		x	x	x
Slovakia					x						x
Slovenia	x	x	x				x	x			
Spain	x	x	x		x	x	x			x	x
Sweden											
Ukraine	x	x	x	x	x		x		x		
UK	x	x	x	x	x	x	x		x	x	x
Contribution (%) of the waste to the total challenging wastes studied in the framework of ROUTES	8	10	10	5	12	9	11	4	11	10	10

Note that empty cases mean that Member State is not facing difficulty in managing the particular waste and so, is not considering this waste as a challenging one.

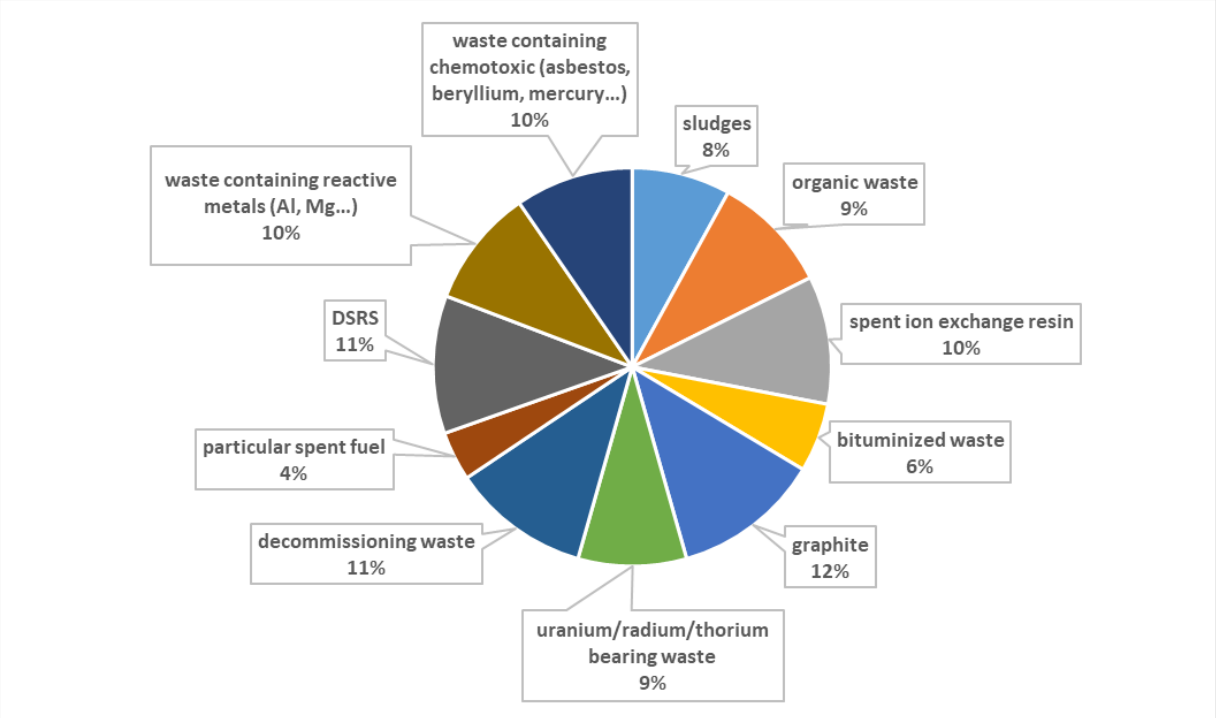

Figure 6: Distribution of the challenging waste that member states are most confronted with

On the basis of Table 5, the pie chart presented in Figure 6 has been prepared and aims to represent the contribution (%) of each challenging waste to the total of challenging wastes identified within ROUTES. From these elements, it is clear that the different MS face on average at least 6 different types of challenging waste, often including spent ion exchange resins, disused sealed radioactive sources (DSRS), decommissioning waste and graphite waste. The exception of Czech Republic and Sweden should be mentioned as waste listed in the questionnaire are manageable in their country, or have at least one identified management routes and therefore, are not challenging as such. However, Sweden raises the particular case of legacy waste for which no management route has been found due to lack of information. Cyprus, Germany and Slovakia are also tree particular MS as they are confronted with only two of the predefined challenging wastes. Belgium also specifies that for uranium/radium/thorium-bearing waste, graphite and spent ion exchange resins, the challenges are mainly related to specific waste streams. Moreover, it is interesting to note that for Austria, most of the challenging waste are considered as such because no final repository is defined yet and therefore, no WAC are available to date. However, for all the waste streams mentioned, Austria does have the technology for treatment up to and including interim storage.

In any case, the analysis of the Table 5 and the Figure 6 confirms that challenging waste already listed in the questionnaire are of interest for both nuclear and non-nuclear MS. This observation is of importance for the rest of the work that will be conducted within the ROUTES project. Indeed, the work on each challenging waste and the related identification of R&D needs will be useful for all the MS and not just those who have an advanced nuclear program.

Moreover, it should be noticed that within the different questionnaires, some MS have mentioned additional challenging waste than those listed in the preliminary list. The section 5.3 offers a description of these particular cases and the reasons why they are considered as challenging.

5.4 Other challenging waste

As mentioned in section 5.2, other wastes than those mentioned in the list of section 5.2 have been identified by some MS as challenging ones. This part describes what these wastes are and why they are considered challenging. Beforehand, it should be noted that the following situations are often specific to a given country. However, it is interesting to mention them insofar as it allows sharing of experience between the different MS.

In Ukraine, waste named "Salt cake", associated to the VVER technology, is problematic for their management as one of their characteristics is to have a high solubility in case of ingress of water. Issues are linked to disposability, and whether treatment and conditioning are needed or not. Ukraine also considers waste resulting from the Chernobyl accident, of which a huge amount has been produced. Their content (various radionuclide inventory, physical and chemical properties) is often unknown due to a lack of characterization.

In Slovakia, "chrompik" waste are also considered as challenging. Those waste are liquid radioactive waste which has been used as a heat-transfer medium for cooling off fuel assemblies at the Bohunice A1 NPP operated from 1972 to 1977. Considered as legacy waste, they are intended for processing and treatment through a vitrification facility. Final products are vitrified waste which, for now, do not comply with the WACs of the Slovak surface repository. Pending a final repository, those waste are placed in an interim storage located within the reactor hall of Bohunice A1 NPP.

In Belgium, some waste packages were discovered in 2013, which were generating a gel-like substance. Aqueous concentrates, ion exchange resins and filters produced on nuclear power plant sites were conditioned in these packages. It was found that the cementitious matrices/fill mortars of these packages were affected by an alkali silica reaction. Those packages have become challenging waste as they cannot be disposed under the present conditions and so, solutions have to be found.

Several MS also mentioned in their questionnaires that they had difficulties with wastes that were conditioned before the WAC for disposal had been established. As a result, the radiological or chemical content is frequently unknown and it's not possible to demonstrate the compliance of those historically conditioned waste with the WAC of the current disposal facility. This particular topic is for instance addressed in the CHANCE EC project[3].

Liquid organic waste, e.g., oil solvents, have also been identified in the answers to the questionnaire as challenging waste. Depending on the interest on those wastes and the safety issues linked to them, they could be part of the challenging waste list.

5.5 Why consider these wastes as challenging ones?

In this section, the difficulties faced by the MS with regard to the above-mentioned challenging waste are detailed. It should be highlighted that the questionnaire already identified a list of potential reasons that could lead the MS to consider these waste as challenging ones. This list, as a first thinking, included in particular:

- No available or reliable inventory;
- Unknown or uncertain characterisation (radiological, physical, chemical);
- No pre-disposal technologies available (sorting, retrieval, transport, conditioning, storage);
- No disposal facilities;
- Wait and see strategy because no existing WAC;
- Technologies available in other MS but not accessible;

[3] https://www.chance-h2020.eu/

- Volumes too small to develop a dedicated facility/technology;
- Lack of or poor knowledge in waste management;
- No or poor public acceptance of the foreseen solution.

The answers provided by the member states gave a better understanding of the difficulties they could face for each type of challenging waste. The tables below (Tables 6 to 16) offer more details of the difficulties encountered for each type of challenging waste.

Table 6: Difficulties encountered by each member state in the management of sludges

sludges	Characterization issues (radiological, physical, chemical)	Non bituminised, solidified sludges have a high content of corrosive constituents	Large volume solid waste	WAC do not exsist	Sampling techniques are under development	Conditioning/treatment	disposal	Lack of, or poor knowledge in waste management
Austria				x			x	
Belgium								
Bulgaria	x				x	x		
Cyprus								
Czech Republic								
Denmark	x	x						x
France	x	x				x		
Germany								
Greece	x			x				
Hungary	x		x					
Lithuania								
Netherlands								
Poland								
Portugal								
Romania								
Slovakia								
Slovenia						x		
Spain	x					x		
Sweden								
Ukraine					x	x		
UK	x					x	x	

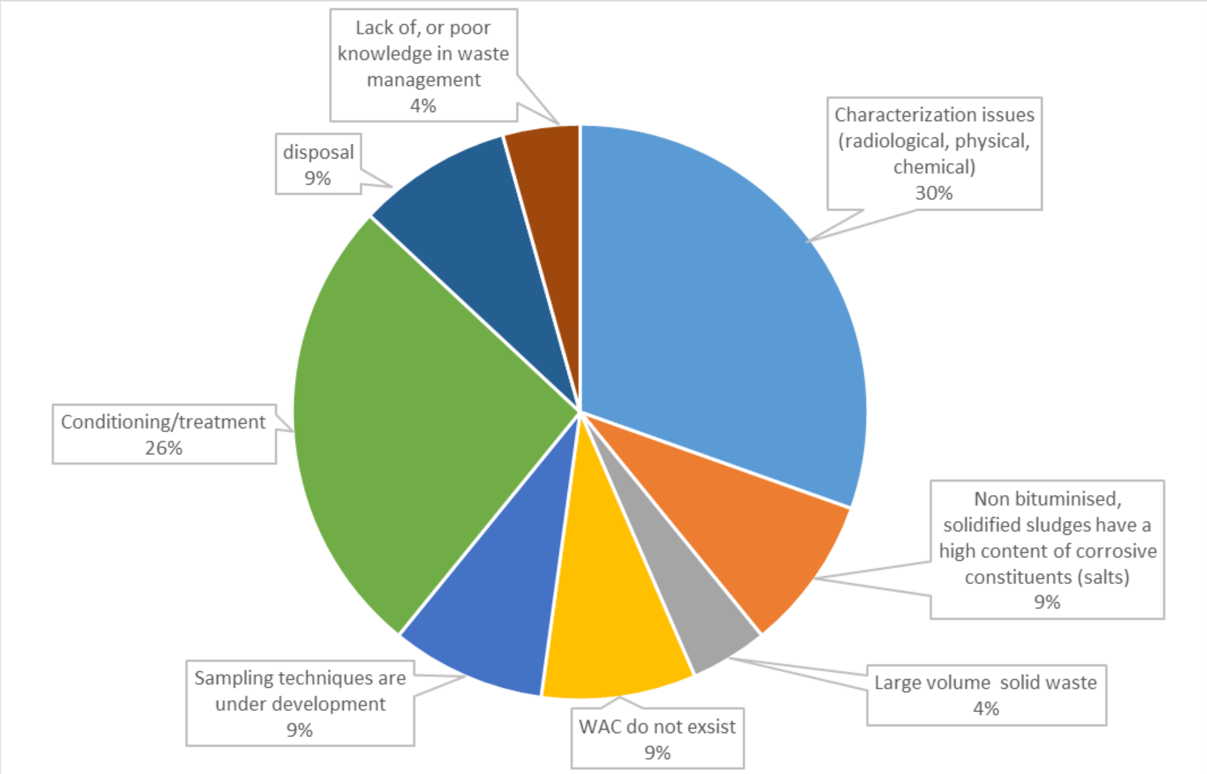

Figure 7: Distribution of the main difficulties encountered in the management of sludges

According to the questionnaire, ten member states identified the case of sludges as challenging waste: Austria, Bulgaria, Denmark, France, Greece, Hungary, Slovenia, Spain, Ukraine and UK.

As it is illustrated in Figure 7, for those member states, the major difficulties related to the management of the sludges concern characterization issues insofar as these sludges contain various radionuclides and reactive chemicals.

For instance, Bulgaria and Ukraine specify in their questionnaires that the sludges are produced by the water treatment activities within their NPP (within Special Water Treatment Installations at Kozloduy NPP) and contain radionuclides such as ^{134}Cs, ^{137}Cs, ^{60}Co and ^{54}Mn (global activity of about 10^{11} Bq) as well as chemical additives. For its side, France mentions the fact that the sludges are concentrated solutions of co-precipitation salts (Barium sulfate, Ferrocynaides, Calcium carbonate, Cobalt sulfide and some others hydroxide). Slovenia also underlines the presence of various corrosive constituents in their sludges.

The MS also raised the question of the treatment and the conditioning of these sludges. Bulgaria and Denmark notably report the fact that studies are ongoing for new technologies and experiments to treat and condition this particular waste. Greece also indicates that it is expected to solidify the sludge in cement before the disposal. The mass percentage of sludge in the mixture will be around 30 %.

Finally, MS also underlined the fact that non-bituminised or solidified sludges can present high content of corrosive constituents which cause conditioning issues. Denmark notably mentioned the high concentration of salts in its non-bituminised sludges that plead to find appropriate treatment processes to limit corrosion effects. Along the same line, France states that different treatments and conditionings are explored to be able to deal with both high concentration level activity and reactive chemicals. Regarding the case of Austria, it is worth to mention that the main difficulty associated with the sludges management is the lack of a final repository. It turns that no difficulties for treatment or conditioning are experienced as such in this country as sludges are nowadays dried and high-pressure compacted. Challenges involving characterization have been faced mostly because of the unknown chemical content of sludges historically cemented but reconditioning processes have been done to cope with this issue. Indeed, sludges which have been historically cemented have been reconditioned and repackaged into new 200 L drums. Note that Greece has also historical drums of sludge which, for now, need to be reconditioned.

In conclusion, “sludge” defines a broad class of challenging waste with different compositions and activity, which mainly come from treatment of effluents (precipitation, evaporation, concentration).

Even though, a single technology able to treat and condition all type of sludges is not a possible option, nevertheless improvement in the management of sludges could be achieved through EC joint programme, with a similar methodology as in the THERAMIN Project.

Table 7: Difficulties encountered by each member state in the management of organic waste

organic waste	Characterization issues (radiological, physical, chemical), inventory	re-conditioned to conform our interim storage WAC (and state-of-the art waste management techniques)	Wait and see strategy because disposal facility is not available	Most of the organic waste is legacy waste and is mixed in drums along with other waste	Poor knowledge of legacy waste	Technologies available in other MS but not accessible	Conditioning/treatment	disposal	Lack of human and financial resources in waste management	Organic waste does not comply with WAC for disposal at near-surface facilities	Too small volumes to develop a dedicated facility/technology	Treatment (incinerator) is uncertain due to incompatibility with available facility	Other available treatment/conditioning methods do not lead to a waste form that is compatible with surface or geological	No or poor public acceptance of the foreseen solution
Austria								x						
Belgium					x					x		x	x	
Bulgaria														
Czech Republic														
Denmark	x			x	x									
France												x	x	
Germany														
Greece							x				x			
Hungary					x		x	x						
Lithuania														
Netherlands														
Poland	x		x				x	x			x			
Portugal	x		x			x	x		x					x
Romania														
Slovakia														
Slovenia							x							
Spain							x				x			
Sweden														
Ukraine	x						x			x				
UK	x						x	x						

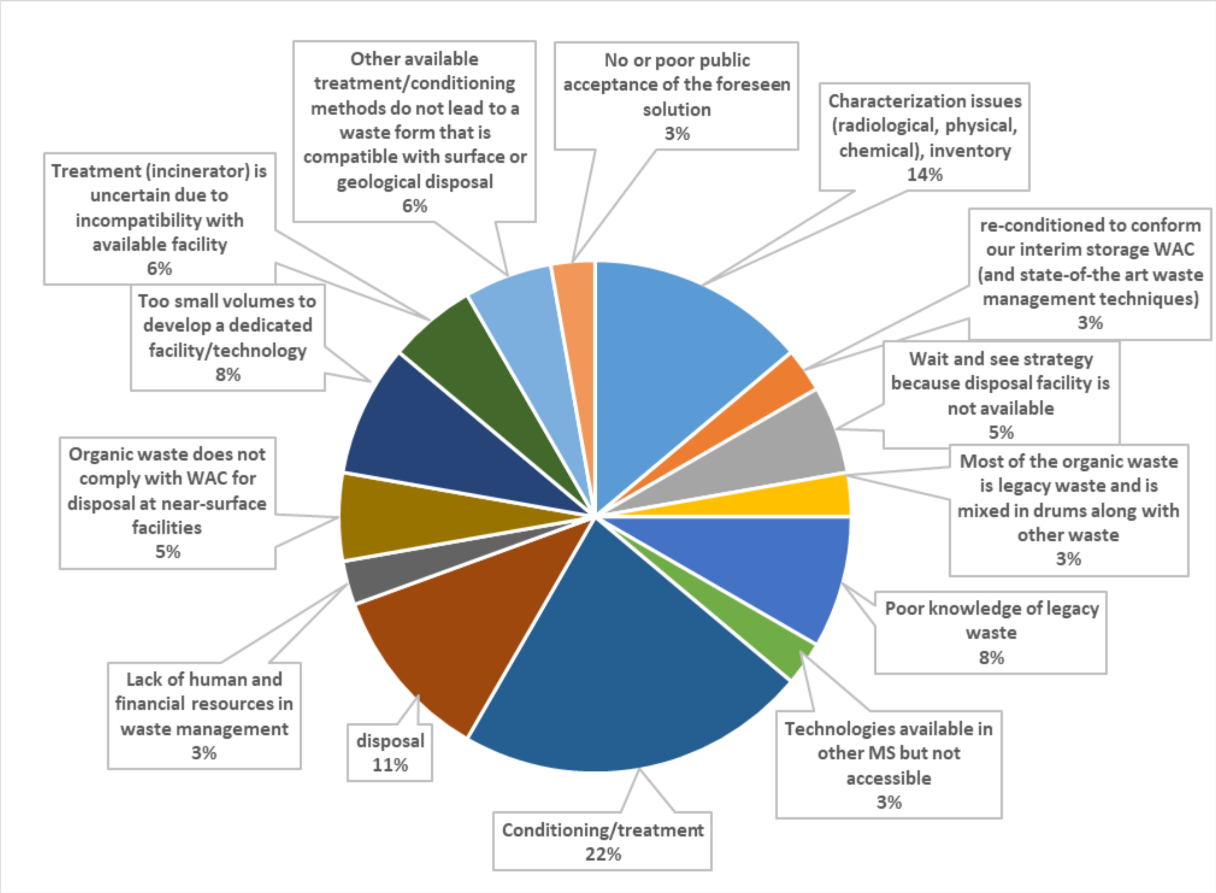

Figure 8: Distribution of the main difficulties encountered in the management of organic

The management of organic waste is a challenge for various member states: Austria, Belgium, Denmark, France, Greece, Hungary, Poland, Portugal, Slovenia, Spain, Ukraine and UK.

According to the responses to the questionnaires, illustrated in Figure 8, it turns out that various difficulties are at stake for the management of this type of waste. In fact, organic waste includes a wide variety of waste that can be either in solid or liquid form.

For example, Belgium, Denmark, Hungary, France and Spain detail that solid organic waste can include plastics, papers, cardboards, elastomers, filters, resins, woods which can give rise to complexing and chelating degradation products which affect the migration of radionuclides (e.g., isosaccharinic acid produces by cellulose degradation). While for liquid organic waste, Spain, Greece or France specify the case of organic solvents, oils, chlorinated organics, etc. On this basis, it is clear that the difficulty most faced by the MS is the treatment and conditioning of this waste. Indeed, the presence of radionuclides and chemical degradation products can lead to the production of corrosive gas and complexing substances that impact the containment properties. Some MS reveal that for the solid organic waste, the choice has been made to encapsulate them in a cement matrix. Austria also mentioned that even if the predominant part of its organic wastes can be treated without difficulties through incineration process, some difficulties arise when wastes are containing too many plastics like PVC. In this case, Austria treats PVC by drying and supercompaction. Note that asphalt and bitumen are also treated this way in Austria. Belgium details for its part that the standard management route for low active beta/gamma waste containing cellulose goes via the incinerator. For all the other organic waste, conditioning in a cementitious matrix is operated, with a maximum limit of cellulose contents (100 times lower for surface disposal than for geological ones). Belgium also testifies that Plasma could offer a solution for the treatment of organic waste but there is no such installation available in the country.

Regarding Portugal, it has been mentioned that no treatment technologies is available for volume reduction, as incineration techniques are not allowed by the government. Note that in Hungary, there is no incineration as well.

However, the management of the liquid organic waste is more difficult. Ukraine mentions that in the Chernobyl NPP, an industrial process is under development trying to treat site runoff water that is contaminated with organic compounds as well as transuranic elements. Moreover, Spain and Greece also point out that due to the small volumes of their organic waste, the development of specific incineration facilities is not viable and so, other treatment and conditioning processes have to be found. France indicates that for liquid organic waste, incineration is not compatible due to the chemical composition and so other processes are under review (e.g., treatment by mixing polymers, specific thermal/chemical destructions, etc.). To this end, the PREDIS project, and especially the WP dedicated to the development of liquid organic waste conditioning processes could result in a sound scientific and technological advance.

The exact characterisation of the organic waste causes also some difficulties, as the radiologic and chemical inventory is not well known. Spain mentions in its questionnaire that their liquid organic waste are expected to have low activity, with mainly beta-gamma and beta emitters. The questionnaires also highlight other difficulties, as for instance for Denmark which most of its organic waste are legacy ones mixed in drums and poor knowledge of the composition is at stake. Austria also states that historically, their organic waste were into 100 Litre drums that have been cemented into 200 Litre drums. Nowadays, those have to be reconditioned to conform with their interim storage and related waste acceptance criteria (WAC).

Table 8: Difficulties encountered by each member state in the management of spent ion exchange resins

spent ion exchange resins	Characterization issues (radiological, physical, chemical), inventory	re-conditioned to conform our interim storage WAC (and state-of-the art waste management techniques)	Wait and see strategy because disposal facility is not available	WAC do not exsist	The resins are considered not suitable for long term storage. Potential processes to condition the radionuclides in the resins are	Technologies available in other MS but not accessible	Conditionning/treatment	disposal	Lack of human and financial resources in waste management	Sampling techniques are under development	Too small volumes to develop a dedicated facility/technology	Treatment (incinerator) is uncertain due to incompatibility with available facility	Other available treatment/conditioning methods do not lead to a waste form that is compatible with surface or geological	No or poor public acceptance of the foreseen solution	Lack of, or poor knowledge in waste management
Austria				x				x							
Belgium	x										x	x	x		
Bulgaria	x						x								
Cyprus															
Czech Republic															
Denmark	x														x
France												x	x		
Germany															
Greece				x											
Hungary															
Lithuania															
Netherlands					x										
Poland															
Portugal	x		x			x	x		x					x	
Romania	x						x	x							
Slovakia															
Slovenia							x								
Spain							x								
Sweden															
Ukraine							x			x					
UK							x	x							

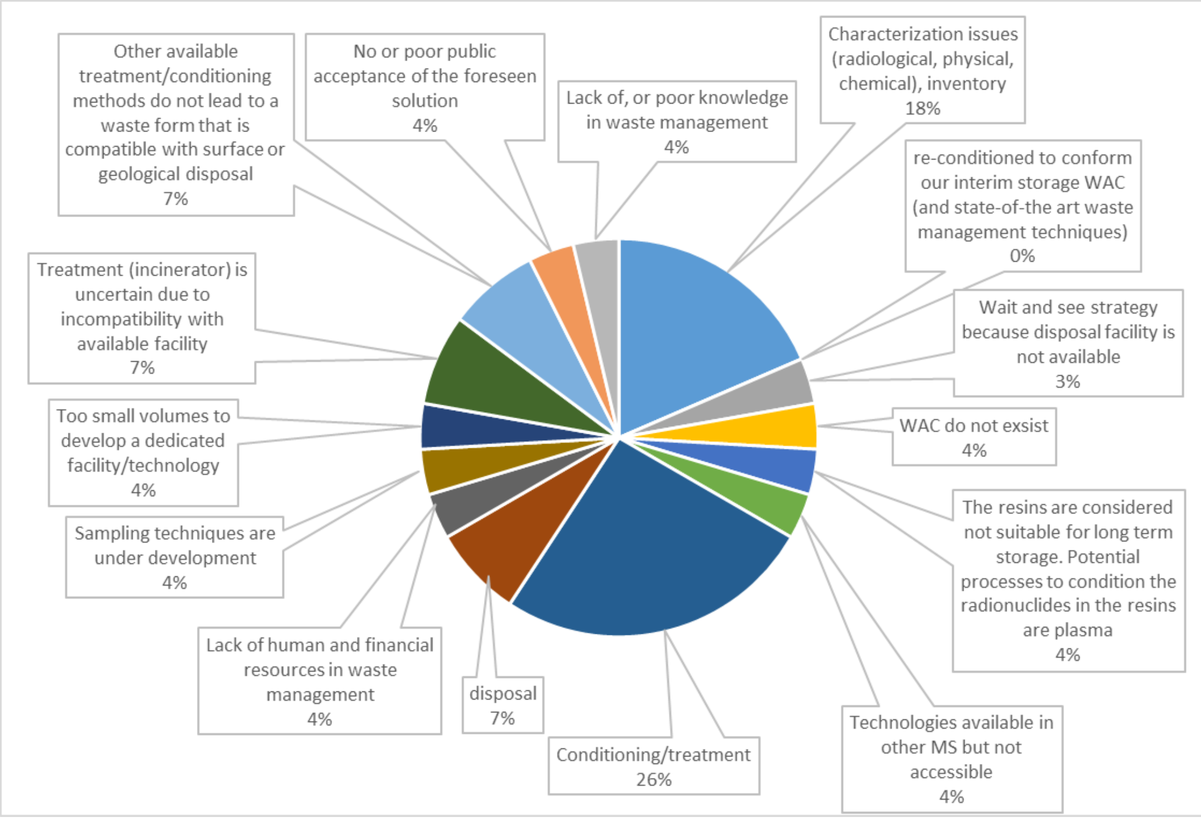

Figure 9: Distribution of the main difficulties encountered in the management of spent ion exchange resins

The question of spent ion exchange resins (SIERs) is in direct link with sludge's issues, insofar as these two types of challenging waste are derived from water treatment and filtration processes. Thirteen MS (Austria, Belgium, Bulgaria, Denmark, France, Greece, Netherlands, Portugal, Romania, Slovenia, Spain, Ukraine and UK) identify the management of SIERs as a challenge.

Indeed, the MS emphasize the fact that the radiological and chemical characterisation of the SIERs is frequently unknown (see Figure 9). Used as primary and secondary circuit filters in NPPs, it is commonly admit that SIERs can include radionuclides like activation products as well as various chemicals. However, the exact characterisation is unclear and some MS like Romania reveals that up to now, no radiological characterisation is performed on its own SIERs. For its part, Ukraine details in its questionnaire that ^{134}Cs, ^{137}Cs, ^{60}Co, ^{54}Mn (global activity of 10^{13} Bq) can be found in its SIERs, as well as corrosion products and chemical additives. Bulgaria also mentioned activity about 10^{13} Bq for its filtering materials (ion-exchange resins).

The complex radiological and chemical inventory of those waste lead to important issues regarding to the treatment and the conditioning. On this topic, Spain specifies that difficulties are at stake in the treatment of SIERS to reduce their volumes. Regarding conditioning, Slovenia mentions that resins conditioned with in drum drying system could swell in contact with water. Denmark indicates that in the past; SIERs have been cast in drums with bitumen, and the knowledge related to the precise characterisation of these drums is poor. Belgium, Greece and Spain intent to condition these resins in a cement matrix. Spain is currently determining the capability of the matrix to contain a maximum amount of resins that will allow enough long term retaining capabilities. The elaboration of innovative matrixes is also ongoing in the Spanish research. In the case of Belgium, resins have been conditioned in cement matrix since the 1980s. However, as it has been mentioned in the section 5.3, in 2013, a gel-like substance has been observed in some packages and the conditioning process has been stopped since then. Other member states are still looking for an appropriate matrix, as for instance Ukraine which is testing the immobilisation of reactive chemicals in non-organic geopolymer matrix. Note that treatment by incineration is ongoing notably in Austria which –in former time- used its incineration facility to treat foreign waste. For its part, the Netherlands are studying the use of plasma incineration to treat the resins. It is worthy to also note that after studies on the use of plasma treatment technology, a Plasma Melting Facility is being commissioned in Bulgaria.

Finally, it should be noticed that the disposal of these waste remains unknown for some MS. In Romania for instance, the SIERS are, for now, stored under water in storage vaults made of reinforced concrete lined with epoxy pending appropriate treatment and final disposal. It is notably mentioned in its questionnaire that “only fuel contact resins would accomplish the WAC for near surface disposal; the non-fuel contact resins, due to the theoretical high C-14 inventory shall disposed of in the future geological disposal facility”.

In conclusion, SIERs represent a widespread class of challenging waste. Most of the difficulties to find a management strategy arise from the fact that SIERs are not compatible with the usual condition matrix. To our knowledge and despite the huge amount of unconditioned SIERs across Europe, no specific EC programme has addressed this topic yet. So, even if this deliverable is not intended to suggest and define future R&D topics, it should be mentioned that the development of characterisation and treatment solutions would represent a huge technological advance.

Table 9: Difficulties encountered by each member state in the management of bituminized waste

bituminized waste	Characterization issues (radiological, physical, chemical), inventory	Storage is challenged because of swelling of bitumen matrix and corrosion of packaging	Compatibility with geological disposal is uncertain because of swelling and chemical composition of the matrix (bitumen)	No reconditioning technology available	Poor knowledge of legacy waste	Disposal availability : transformation of storage to disposal	Conditionning/treatment	disposal	These RW were conditioned in absence of WAC for disposal	Exothermic reactions
Austria										
Belgium		x	x	x						
Bulgaria										
Czech Republic										
Denmark	x		x		x					
France		x	x	x						x
Germany										
Greece										
Hungary										
Lithuania						x				
Netherlands										
Poland										
Portugal										
Romania										
Slovakia										
Slovenia										
Sweden										
Ukraine			x		x			x	x	x
UK								x		

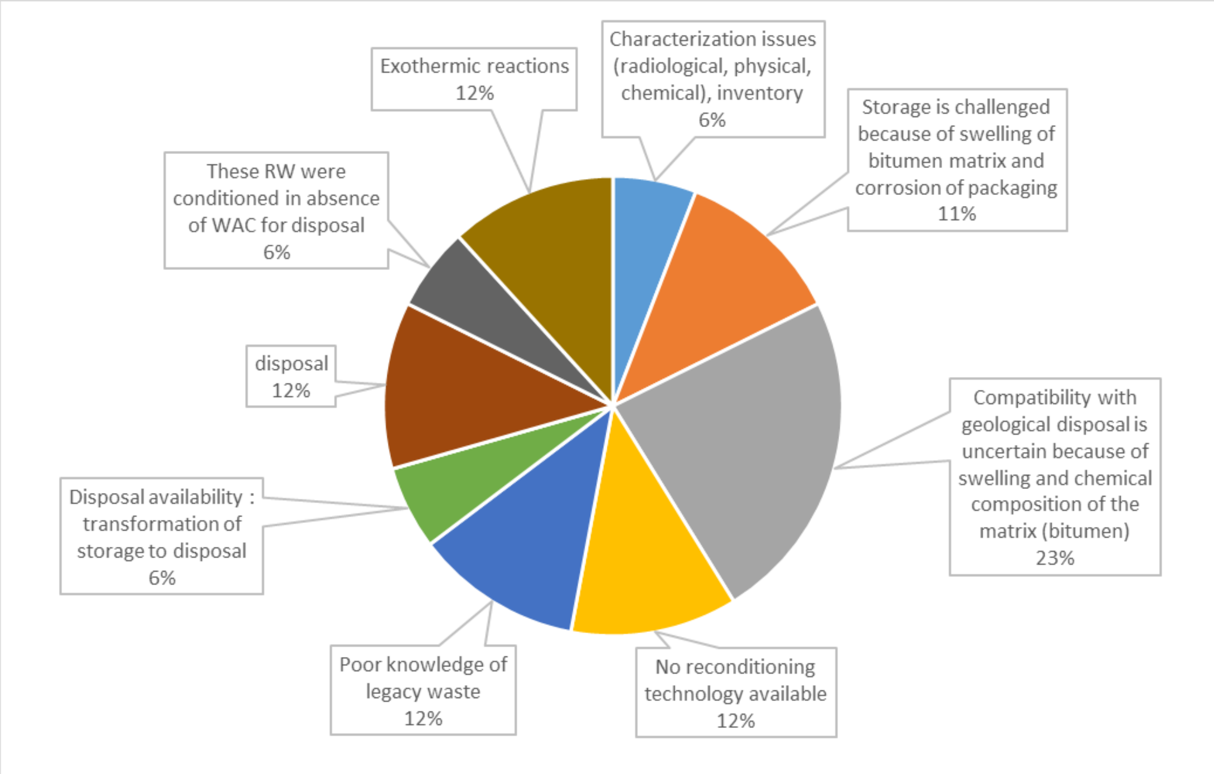

Figure 10: Distribution of the main difficulties encountered in the management of bituminized waste

Most of the bituminized waste correspond to the conditioning of spent resins and effluent sludge, often associated with fuel reprocessing plants. Bitumen was indeed the matrix mainly used from the 1960s to stabilize those reactive waste. Today, various MS are looking for solutions for the management of bituminized waste (Belgium, Bulgaria, Denmark, France, Lithuania, Ukraine and UK).

As Belgium points out, bituminized waste can be homogeneous or heterogeneous and contain both radionuclides and chemicals (notably salts). In the particular case of Belgium, the homogeneous bituminized waste have medium activity (around 1 Sv/h) and the heterogeneous ones have low activity (from 0.1 to 1 mSv/h).

As Figure 10 shows, the main difficulty encountered by the MS when dealing with those bituminized waste is the question of their compatibility with the envisaged disposal and the disposal itself. Indeed, as France has underlined it in its questionnaire, the bituminized wastes have a potential for exothermic chemical reactions. Belgium also highlights that radiolysis and chemical reactions can cause swelling of the bitumen matrix and corrosion of the packaging. This raises various questions related to safety. Belgium notably specifies that for the medium active bituminised waste, the compatibility with geological disposal is currently uncertain. And it is the same for the compatibility between their low active bituminised waste and their surface disposal. France, for its part, has launched an R&D program to demonstrate the safety of bituminized waste behaviour in deep geological disposal, regarding fire risks in particular. In addition to that, France is also studying methods of processing and conditioning bituminous mixtures combining chemical and thermal processes. Ukraine also underlines the fact that those wastes were conditioned in absence of WAC for disposal.

Regarding Lithuania, a project is currently considering transforming the legacy bitumen storage facility into a repository. In Denmark, bituminised wastes are considered as legacy waste and so, the lack of information on radiological and chemical inventory makes things tougher for the management.

Table 10: Difficulties encountered by each member state in the management of Uranium/radium/thorium bearing waste

thorium uranium radium bearing waste	Characterization issues (radiological, physical, chemical), inventory	no available or reliable inventory	Wait and see strategy because disposal facility and WAC are not available	uncertainty about the management route	decisions must be taken with safeguards regulation	Technologies available in other MS but not accessible	Conditionning/treatment	disposal	Lack of human and financial resources in waste management	no pre-disposal technology available	Too small volumes to develop a dedicated facility/technology	No or poor public acceptance of the foreseen solution	Lack of, or poor knowledge in waste management	WAC do not exsist
Austria								x						x
Belgium				x										
Bulgaria														
Cyprus	x						x	x	x					
Czech Republic														
Denmark	x				x		x						x	
France							x	x						
Germany														
Greece								x						x
Hungary														
Lithuania														
Netherlands														
Poland	x		x				x	x		x	x			
Portugal	x	x	x			x			x	x		x		
Romania				x										
Slovakia														
Slovenia														
Spain	x						x	x						
Sweden														
Ukraine														
UK	x						x	x						

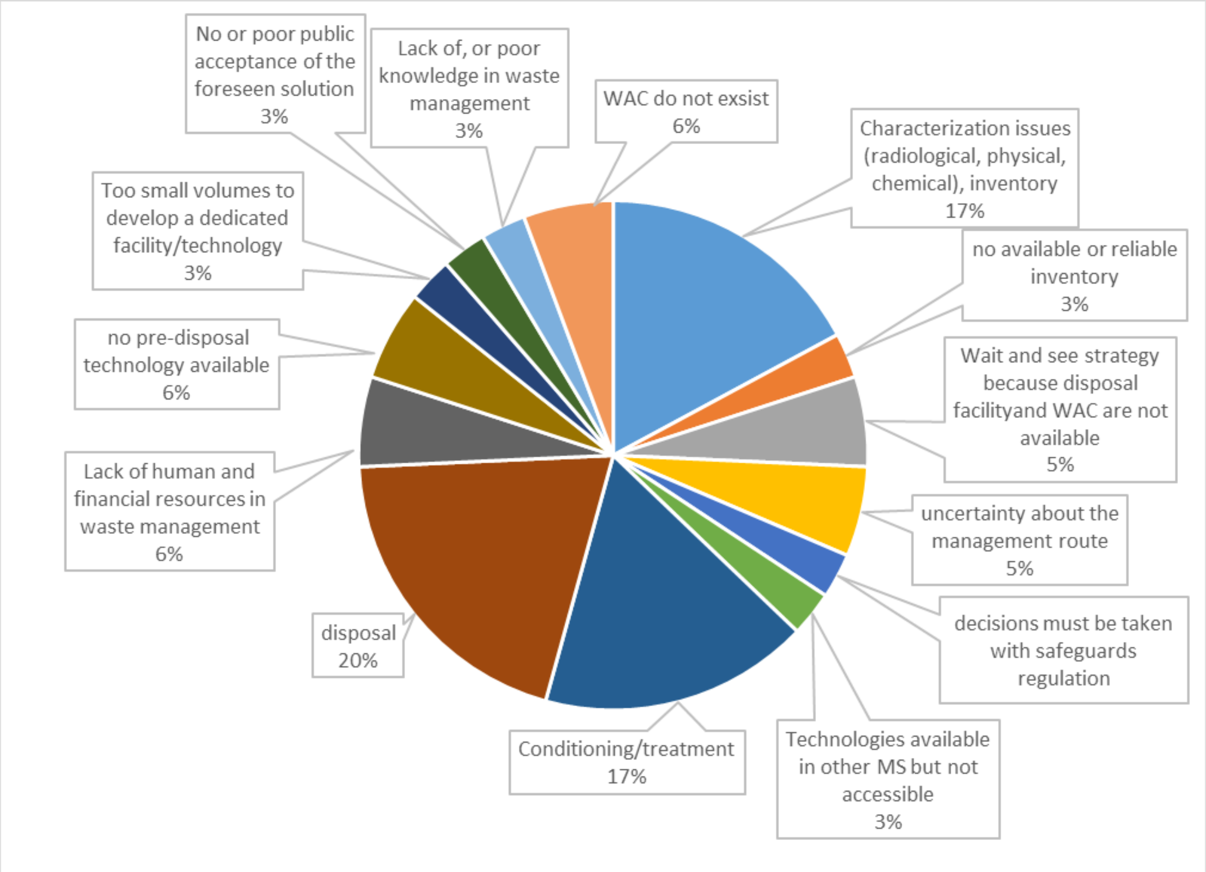

Figure 11: Distribution of the main difficulties encountered in the management of uranium/radium/thorium bearing waste

As regards uranium/thorium/radium waste, among which some can be considered as NORM, number of Member States consider those as challenging waste: Austria, Belgium, Bulgaria, Cyprus, Denmark, France, Greece, Poland, Portugal, Romania, Spain and UK.

According to the questionnaires, those waste can take various forms: radium waste from the dismantling of a former radium factory in Belgium, former research activities in Belgium and Poland waste ranging from powders containing uranium to pieces of spent fuel used in research centers in Denmark and Greece, products of the exploitation of gypsum by the fertilizer industry in Cyprus, etc. In Austria, those waste are mostly from medical applications in Austria, but also from decommissioning and decontamination of historical facilities and laboratories as well as residues from fertilizer industries. ,. From its side, Bulgaria does not mention that such waste are present in the country but indicates a lack or poor knowledge of them and their management.

For all of those waste, MS reveal that they have difficulties regarding their real radiological and chemical inventory on the one hand, and with the definition of their routes of management on the other hand (see Figure 11).

For instance, Denmark states that for now, safety regulations on those waste are expected. Regarding Austria, radium sources from medical applications have been welded into capsules, placed lead shielding which turn was placed in a drum with a concrete liner. Cyprus, for its part, announces that there is some risks to the long-term stability of its waste and their related spread in the environment. It is also specified that no treatment or disposal facility is set up in Cyprus and in any case, it would not be economically viable.

Table 11: Difficulties encountered by each member state in the management of graphite waste

graphite waste	Characterization issues (radiological, physical, chemical), inventory	Compatibility with surface disposal is uncertain because of relatively high concentration of C-14	Graphite waste management is poorly known	Technologies available in other MS but not accessible	Conditionning/treatment	disposal	Lack of human and financial resources in waste management	Too small volumes to develop a dedicated facility/technology	No or poor public acceptance of the foreseen solution
Austria						x			
Belgium		x	x		x				
Bulgaria									
Cyprus									
Czech Republic									
Denmark			x						
France					x				
Germany	x	x	x		x				
Greece	x		x			x		x	
Hungary									
Lithuania						x			
Netherlands								x	
Poland								x	
Portugal				x	x		x		x
Romania			x		x	x			
Slovakia	x		x						
Slovenia									
Spain		x			x	x	x		
Sweden									
Ukraine	x					x			
UK	x	x	x		x	x			

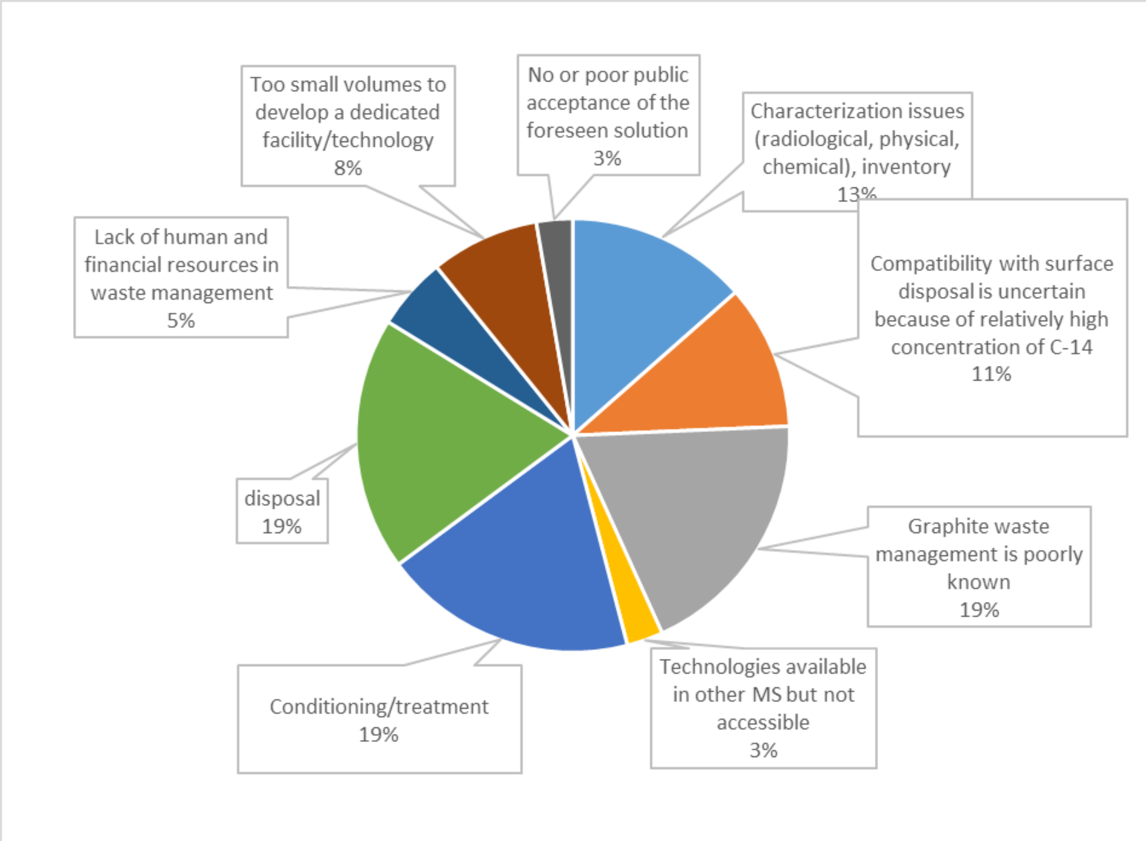

Figure 12: Distribution of the main difficulties encountered in the management of graphite waste

Graphite waste come from both former nuclear research and nuclear production reactors. Depending on their position within the reactor (stack from reactor core or graphite cells from the radioprotection system), those waste were more or less in contact with the fuel and therefore, more or less activated. Nowadays, graphite waste are considered inert but highly flammable.

With regard to the management associated with those waste, the fifteen MS concerned (Austria, Belgium, Denmark, France, Germany, Greece, Lithuania, Netherlands, Poland, Portugal, Romania, Slovakia, Spain, Ukraine, UK) reveal several difficulties (see. Figure 12).

First, the MS agree that the graphite waste management is poorly known. Indeed, those waste present different challenges in terms of safety as for instance, the mobility of C-14 emphasized by Greece or the Wigner effect mentioned by Austria, Belgium, Denmark and Greece. However, no solution has been found to overcome these safety issues except for Austria where all graphite wastes exposed to a fast neutron fluence of $>10^{19}$ n/cm^2 at low temperature (<50°C) was heat-treated at 370°c to release 95% of the Wigner Energy. In relation with this difficulty, the MS also underline the absence of appropriate treatment and conditioning.

Germany points out that highest active graphite comes from the pebbels of the HTR reactor. It is also mentioned that the graphite waste contain activation or even fission products. France also mentions the fact that in its waste, magnesium and uranium can be included causing problems in case of conditioning in an usual cement-based matrix. Therefore, for the majority of MS, those waste are currently stored without preliminary treatment or appropriate conditioning. In Denmark, for example, graphite waste are stored in steel containers 10 mm thick. In Romania, graphite blocks are stored in the spent fuel pools hall and the graphite rings are stored inside the storage pools. In Slovakia, graphite waste are still inside the reactor, waiting for a management route. However, in Germany, reactor vessel from AVR has been filled with the light cement for binding graphite dust and all radionuclides associated with it. The filled reactor vessel is currently stored in the interim storage.

For Greece, those waste will be produced after the dismantling of their nuclear research reactor. For the Greek case; the expected partitioning of those waste is 33 % Exempt, 60 % VLLW, 6 % LLW and 1 % ILW. The graphite will be possibly disposed of in blocks without any treatment. Nevertheless, shielding or barriers will be necessary for LLW and ILW. It should also be stressed that for some of these MS, the small volume associated with graphite waste (e.g., 5.6 m3 in Greece) does not justify the development of appropriate treatment or conditioning processes. For Portugal, the decommissioning of the Portuguese Research Reactor (RPI) will produce around 3 m3 of graphite waste, representing about 4,8 tonnes. The way this small volume of waste will be treated and managed is still unknown in this country as well.

Finally, it should be noted that, for now, for most of the MS, there is no disposal route. For instance, Ukraine is waiting for decisions regarding the dismantling of the Chernobyl reactors and Belgium reveals the incompatibility between its graphite wastes containing C14 and its surface disposal. In France, a shallow depth disposal is studied for graphite waste.

Table 12: Difficulties encountered by each member state in the management of decommissioning waste

decommissioning waste	Characterization issues (radiological, physical, chemical), inventory	Compatibility with surface disposal is uncertain because of large amount of waste	no availible facility for release of contaminated soil	large items may be difficult to dispose of in some types of disposal facilities	Wait and see strategy because disposal facility is not available	Technologies available in other MS but not accessible	Conditionning/treatment	disposal	Lack of human and financial resources in waste management	specific clearance criteria for decommissioning waste streams are not established	Too small volumes to develop a dedicated facility/technology	regulation for hazardous material	Technologies available in other MS but not accessible	No or poor public acceptance of the foreseen solution
Austria								x						
Belgium	x	x	x	x									x	
Bulgaria	x	x		x			x					x		
Czech Republic														
Denmark	x			x										
France		x											x	
Germany														
Greece	x				x									
Hungary														
Lithuania												x		
Netherlands														
Poland	x				x		x	x			x			
Portugal	x				x	x	x		x					x
Romania	x							x						
Slovakia														
Slovenia	x													
Spain	x													
Sweden														
Ukraine	x									x				
UK	x	x		x			x	x						

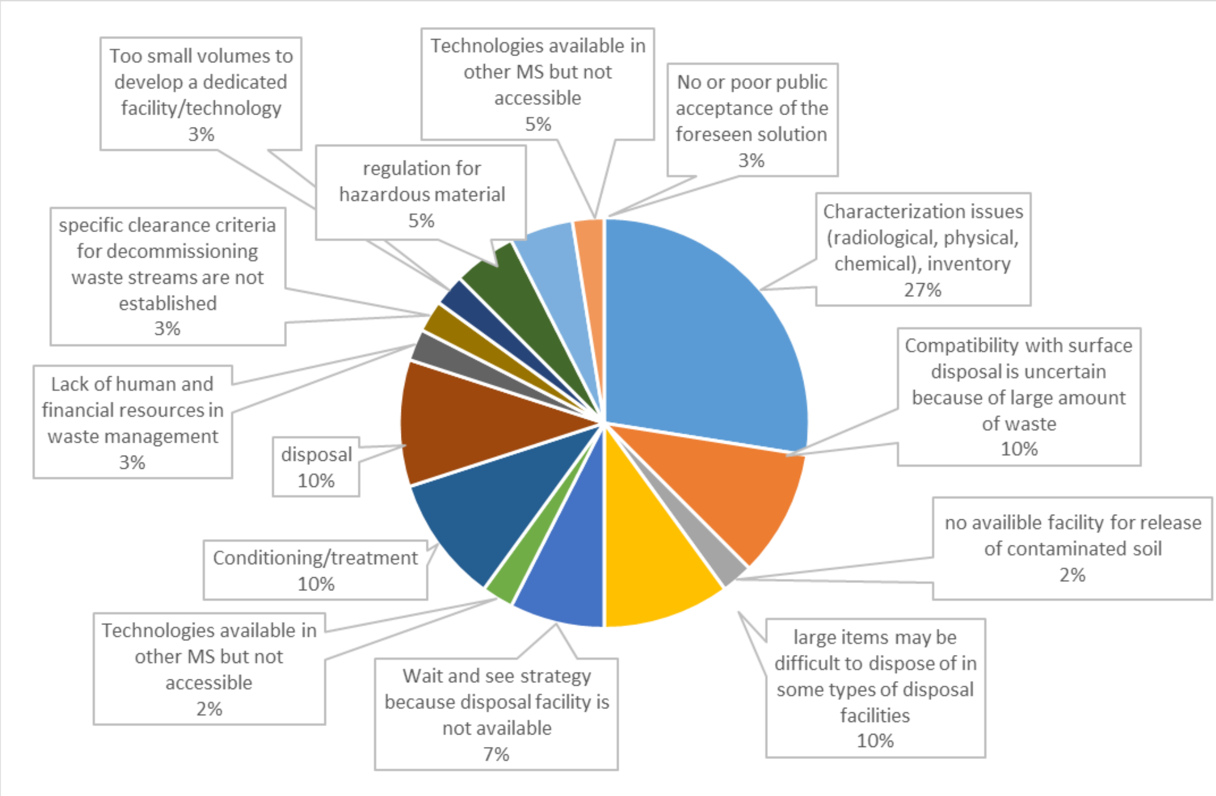

Figure 13: Distribution of the main difficulties encountered in the management of decommissioning waste

Waste related to decommissioning activities are diverse and can be found in both solid and liquid forms. Therefore, the 14 Member States concerned by this issue (Austria, Belgium, Bulgaria, Denmark, France, Greece, Lithuania, Poland, Portugal, Romania, Slovenia, Spain, Ukraine, UK) testify that decommissioning waste can correspond to construction materials (e.g., rubbles, contaminated concrete), soils, scrap metal, wood, or even various tools and safety equipment.

In order to manage such a diversity of waste, the MS highlight several difficulties (cf. Figure 13). First, the difficulty of obtaining precise radiological and chemical inventories for all these types of waste has been underlined. Anticipating the precise quantities of waste to be produced seems to be also a difficult task. For instance, Lithuania reveals that strong uncertainties persist on the quantity of contaminated concrete that they will have to manage. Similarly, Slovenia insists on the need to carry out additional calculations to obtain more reliable estimations.

The MS also raises treatment and conditioning as a challenging issue. Indeed, with the diversity of waste, it turns out that the MS are considering several possibilities. Greece, for example, intends to use super compaction and cementation techniques for the steel coming from the future decommissioning of its research reactor. Denmark, for its part, is packing its waste in Dekom steel containers and a part of the waste containers are supplemented with an inner shielding. Bulgaria also indicates that the Specialized Division “RAW-Kozloduy” is dealing with about 71 % cemented liquid RAW, almost 4 % bulk RAW and barrels with solid RAW for the rest. In Austria, decommissioning waste are treating and conditioning by drying and supercompaction techniques. In case of liquid waste, they are either dried after chemical treatment or incinerated, which and ends as dried and supercompacted sludge or ashes in the Austrian interim storage. In Ukraine, the decommissioning of the Chernobyl NPP has led to the creation of treatment facilities, one dedicated to liquid treatment and the other dedicated to solid treatment. For the solid treatment plant, which is under commissioning, it is intended to treat (fragmentation, incineration, compaction, cementation) low and intermediate level short lived solid waste.

Moreover, it should be noted that when talking about decommissioning waste, this frequently implies large volumes and some specific waste. In that sense, some MS point out that these volumes make it difficult to comply with the WAC of the final disposals. This is the case for Denmark, Lithuania and Belgium. Note that in the case of Belgium, they envisage decay storage for the management of the contaminated concrete. Finally, it is interesting to note the problem raised by Lithuania, which emphasizes that some of its decommissioning waste are hazardous radioactive waste and do not comply with existing WAC due to its hazardous properties.

Table 13: Difficulties encountered by each member state in the management of particular spent fuel

particular spent fuel	no available facility for some of the considered treatment/conditioning options	pre-disposal handling not available	Wait and see strategy because disposal facility is not available	disposal
Austria				
Belgium	x			
Bulgaria				
Cyprus				
Czech Republic				
Denmark	x	x		
France				
Germany				
Greece				
Hungary				
Lithuania				
Netherlands				x
Poland				
Portugal				
Romania				
Slovakia				
Slovenia				x
Spain				
Sweden				
Ukraine				
UK				

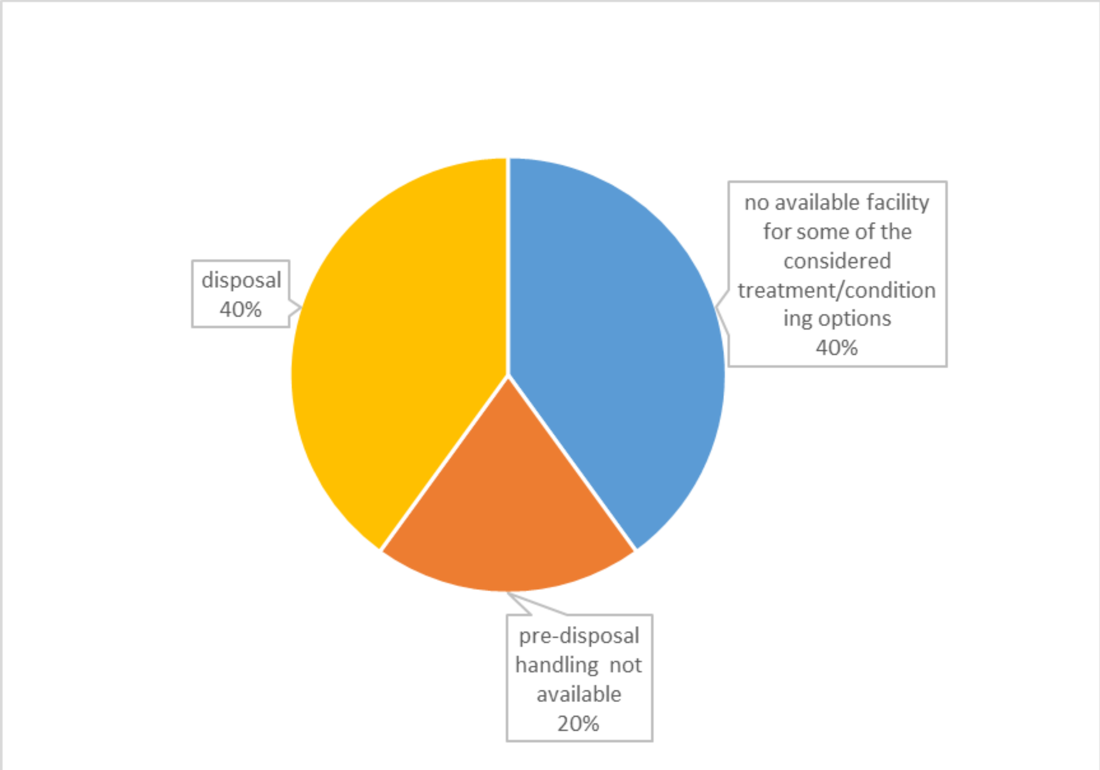

Figure 14: Distribution of the main difficulties encountered in the management of particular spent fuel

The challenges associated with the management of particular spent fuel were raised by some member states (e.g., Belgium, Netherlands, Denmark and Slovenia). In particular, they raised the fact that they lack facilities for treating or containing these wastes as well as final disposal (cf. Figure 14). In the case of Belgium, it is interesting to point out that spent fuel is not yet considered as "waste", since ONDRAF/NIRAS still consider it as a reusable resource.

Table 14: Difficulties encountered by each member state in the management of disused sealed radiation sources

DSRS	Characterization issues (radiological, physical, chemical), inventory	no available or reliable inventory	Difficult to identify source or to retrieve reliable documentation	Wait and see strategy because disposal facility is not available	The necessary transport certificates are not always available	suitable containers for long term storage not presently available	Technologies available in other MS but not accessible	Although the disposal concepts have been defined (i.e. borehole or/and engineered near surface), decisions for the establishment of the disposal facilities have not reached yet	disposal	Lack of human and financial resources in waste management	no predisposal technology available	mixed sources and waste	Necessity and approaches for determination of specific activities of disused SRS (aimed at their disposal).	conditioning treatment	No or poor public acceptance of the foreseen solution	Lack of, or poor knowledge in waste management	WAC do not exsist
Austria									x								x
Belgium			x		x												
Bulgaria	x			x								x	x				
Cyprus	x								x	x				x		x	
Czech Republic																	
Denmark						x											
France						x			x					x			
Germany																	
Greece				x				x									x
Hungary									x					x			x
Lithuania			x	x					x			x					x
Netherlands																	
Poland				x													
Portugal		x		x			x			x	x				x		
Romania									x								
Slovakia																	
Slovenia																	
Spain																	
Sweden																	
Ukraine			x						x			x	x				
UK	x								x					x			

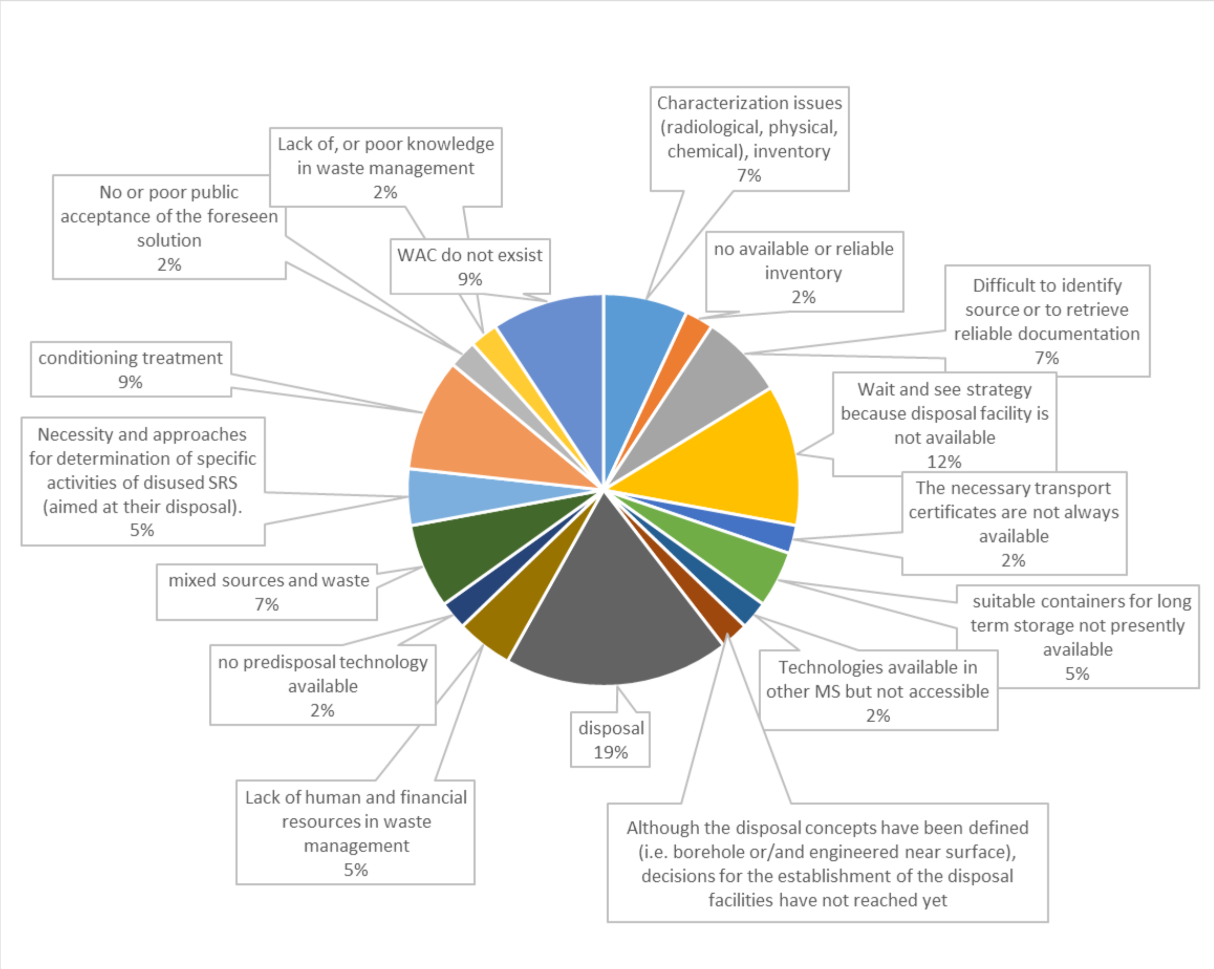

Figure 15: Distribution of the main difficulties encountered in the management of disused sealed radiation sources

For the 14 Member States for which the management of disused sealed radiation sources (DSRS) is challenging (e.g., Austria, Belgium, Bulgaria, Cyprus, Denmark, France, Greece, Hungary, Lithuania, Poland, Portugal, Romania, Ukraine, UK), several difficulties have been highlighted (cf. Figure 15).

Firstly, some Member States, such as Poland, Belgium, Cyprus, Greece and Portugal point out that DSRS can concern a wide variety of waste: disused measurement devices, smoke detectors, calibration sources, medical and research sources, lightning rods, etc. Therefore, Ukraine mentions that DSRS imply large volumes of waste with various radionuclides that have a wide range of radiological activities. In addition, it turns out that various economic sectors use these sources (industry, medicine, research), which complicates their identification and characterisation. Denmark, for its part, specifies that DSRS have been produced for more than 50 years and that some of the DSRS are now considered as historical waste.

On this basis, some Member States such as Belgium and Greece raise the difficulty of retrieving reliable documentation and certificates to determine the accurate activity of these waste. Belgium also points out that for some sealed sources, even transport certificates are not available.

In terms of management route, different options are chosen by the Member States. Some DSRS are stored in temporary storage sites, as in Bulgaria (where the DSRS and orphan sources are stored separately, in dedicated containers) and Denmark. Other DSRS are kept by their users like in Belgium or in Cyprus (Nicosia General Hospital) awaiting a management solution to be found. In fact, for most of the MS, the question of final disposal has not yet been settled. In Greece for instance, short lived DSRS are managed by radioactive decay and clearance options.

For the most active DSRS, some are sent abroad for recycling but the others remain with a pending management. The idea of borehole or/and engineered near surface disposal is being considered by Greek authorities, but decisions still have to be made. Denmark, for its part, is considering recycling and is waiting for the conception of suitable containers for long-term disposal. In Portugal, some industrial disused/spent sources (mainly Cs-137 and Co-60) and lightning rods (Am-241 and Ra-226) are cemented in 200 l drums which are stored in an interim storage. However, no management routes has been identified yet as the technology to minimize the volume of these drums is not available in Portugal. In Austria, the presence of long-lived radionuclides like Am-241 also raised some questions regarding the final disposal. Some near-surface or borehole options are envisaged. However, it should be noted that for some MS, several disposal projects exist, either in Bulgaria, where DSRS will be managed in two facilities (*National Disposal Facility for low and intermediate level short-lived waste* and *the facility for intermediate long-term storage of HLW*) or in Ukraine (*Centralized Facility for Long-Term Storage of Disused SRS at the Vector Complex in Chernobyl exclusion zone*). France, for its part, has announced that according to their activities, some DSRS are not compliant with the existing disposal waste acceptance criteria. Lithuania highlighted that some of stored DSRS are mixed with operational radioactive waste and it is not possible to identify due its small size and separate them from radioactive waste. Therefore, various research projects are undertaken as for instance: define and deploy packaging solutions specific for the sources, define and deploy disposal, create interim storage capacity (especially for tritiated sources), etc.

The case of DSRS considered as historical waste and which have already been sent in the past in Radon-type facilities or “well-type” disposals should also be highlighted. Lithuania and Ukraine are notably facing this problem and have to deal with particular issues like the fact that these DSRS are mixed with other type of waste or need to be reconditioned.

Table 15: Difficulties encountered by each member state in the management of waste containing reactive metals

waste containing reactive metals	Characterization issues (radiological, physical, chemical)	Inventory has not yet been established	Wait and see strategy because disposal facility is not available	Uncertainty about the management route, because of the reactivity of metallic uranium (pyrophoric reactions, generation of hydrogen gas)	Al Compatibility with geological disposal is uncertain because of potential gas generation (in the long term)	new waste type with large amount	Conditionning/treatment	disposal	sorting operation
Austria								x	
Belgium				x	x				
Bulgaria									
Czech Republic									
Denmark	x	x							
France					x		x		
Germany									
Greece			x						
Hungary			x			x	x		
Lithuania									
Netherlands									x
Poland	x								
Portugal	x								
Romania				x			x	x	
Slovakia									
Slovenia									
Spain	x			x			x	x	
Sweden									
Ukraine									
UK	x						x	x	

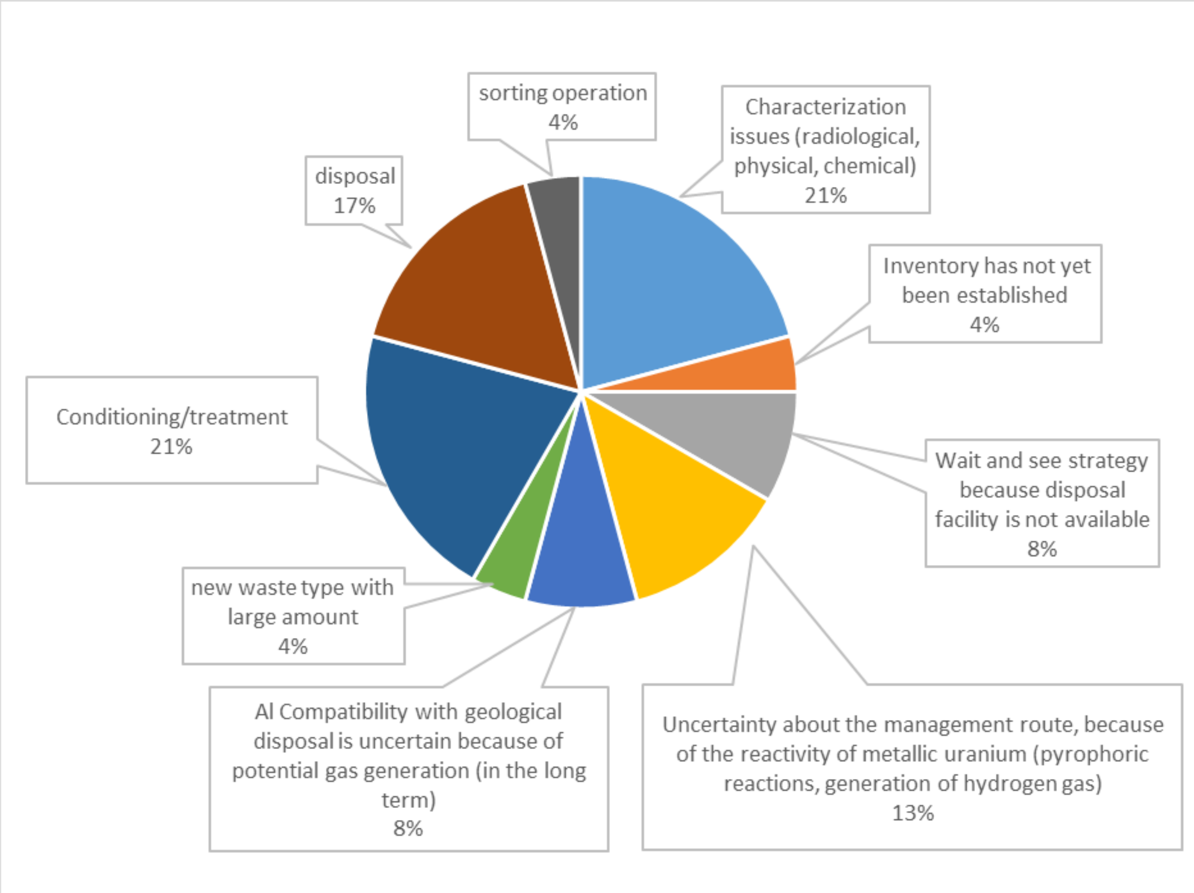

Figure 16: Distribution of the main difficulties encountered in the management of waste containing reactive metals

With regard to waste containing reactive metals, at least 12 Member States (Austria, Belgium, Denmark, France, Greece, Hungary, Netherlands, Poland, Portugal, Romania, Spain and UK) report difficulties related to their management (see Figure 16).

It turns out that waste containing reactive metals often come from the nuclear production cycle or during the decommissioning of research or production nuclear reactors. Depending on their origin, those wastes can present different proportions of metals (e.g., Al, Be, Mg, U, etc.). In that sense, Denmark and Portugal raise the fact that there is no clear inventory of the metal content in its waste. In addition, it is interesting to underline the case of France that has to manage boron carbide (B_4C) rods coming from assemblies of control systems for the fast neutron reactors. These fuel rods may contain residual metallic sodium, which was not removed during the washing operations and whose storage behaviour remains uncertain. From its side, Austria reports not having metallic sodium and that it has treated its metallic waste mostly by melting as a form of decontamination at external facilities. According to the answers to the questionnaires, the greatest difficulty encountered by the MS is the fact that the behaviour of these activated metals under storage conditions can lead to the generation of gas, following various chemical reactions. As Belgium points out, waste containing reactive metals are neither compatible with surface disposal (radiological activity too high), nor compatible with a deep disposal (reactions with water and gas production). For now, the Netherlands, Belgium and Romania stress that there is no solution for treating or conditioning those waste.

Some MS have decided to store their "metallic" waste in stainless steel containers hosted inside 260 l cast iron containers (Romania) or in metal racks inserted in 1.5m^3 stainless steel containers (France). It should be noted that in France, the case of metallic sodium is the subject of dedicated research groups. Some studies are ongoing to characterise the reaction between sodium and water (liquid and water vapour) under storage conditions, with the aim of defining an acceptance threshold for a limited quantity of sodium in waste packages. Studies are also conducted for processes allowing the elimination of sodium in those wastes.

Table 16: Difficulties encountered by each member state in the management of waste containing chemotoxic substances (asbestos, beryllium, mercury)

waste containing chemotoxic	Characterization issues (radiological, physical, chemical), inventory	inventory has not been yet established	Uncertainty about the management route, because beryllium is a highly electropositive metal (gas generation in disposal conditions may be a challenge)	The resins are considered not suitable for long term storage. Potential processes to condition the radionuclides in the resins are plasma	Conditionning/treatment	disposal	Lack of, or poor knowledge in waste management	mixed waste	difficulty as for hazardous material / diffrent regulation	new type of waste, large volume
Austria						x				
Belgium										
Bulgaria										
Cyprus										
Czech Republic										
Denmark		x								
France					x				x	
Germany	x	x	x		x		x			
Greece	x				x	x				
Hungary					x	x				x
Lithuania	x				x					
Netherlands				x			x			
Poland										
Portugal										
Romania			x		x	x				
Slovakia		x						x		
Slovenia										
Spain	x				x				x	
Sweden										
Ukraine										
UK	x				x	x				

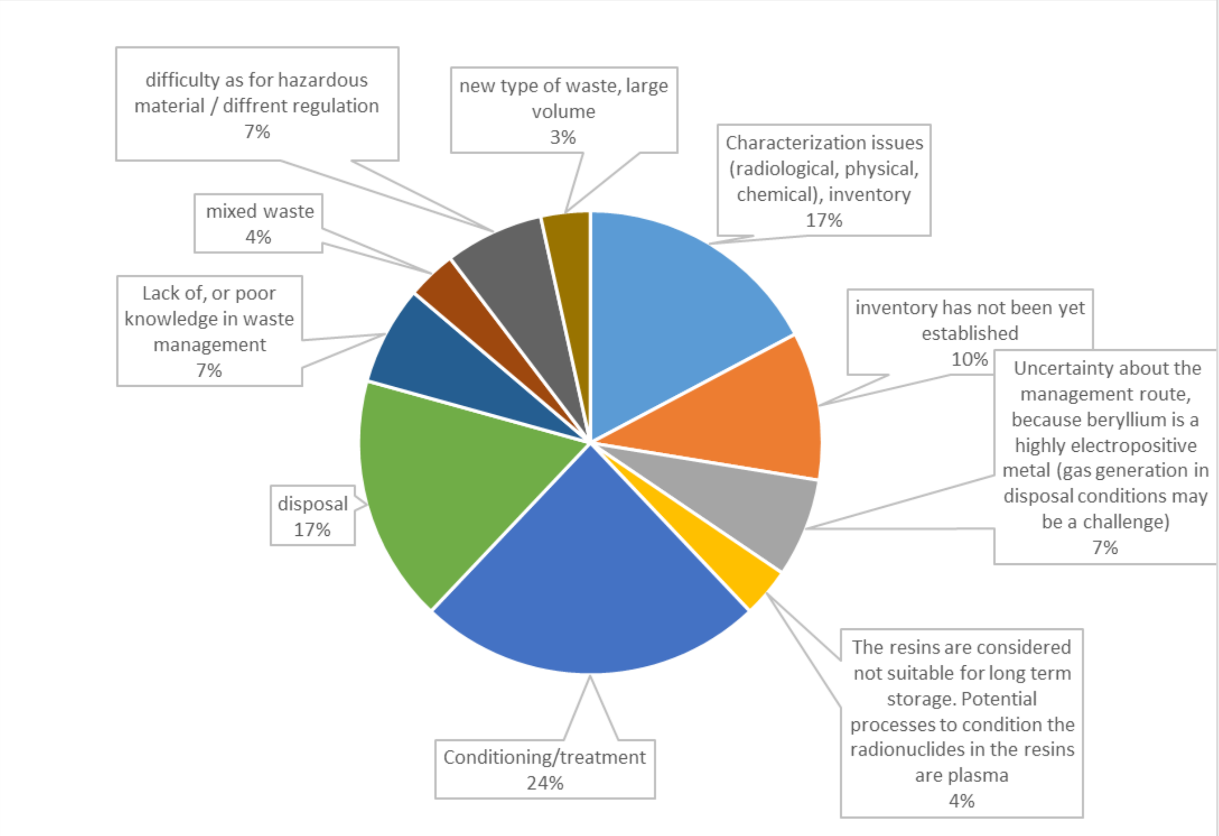

Figure 17: Distribution of the main difficulties encountered in the management of waste containing chemotoxic substances (asbestos, beryllium, mercury)

The management of waste containing chemotoxic substances is a challenge for about 12 Member States (Austria, Denmark, France, Germany, Greece, Hungary, Lithuania, Netherlands, Romania, Slovakia, Spain and UK).

Those waste, often resulting from production or decommissioning activities, can contain a wide range of chemotoxic substances (e.g., Cd, Hg, Be, etc.). As Germany points out, Mercury is an inert material most of the time but can be transformed into toxic vapour under storage conditions and form possibly toxic Hg-organic compounds due to the storage with oil for sealing. Among the difficulties expressed by the MS (cf. Figure 17), the question of the exact chemical characterization of those waste is often mentioned. This was notably expressed by Greece and Germany. It should also be highlighted that, for now, treatment and conditioning options are not available and there is poor knowledge regarding the possible management route of those wastes. Germany states that mercury-containing waste are currently stored in plastic containers in their interim storage. Greece, for its part, raises the lack of final disposal available for those particular wastes. Lithuania states that treatment and conditioning options for chemotoxic radioactive waste is under consideration. For its part, Spain specifies that a new program for characterization of toxic and hazardous waste is in development for surveillance of fulfilment with the waste acceptance criteria. For its side, Austria specifies that beryllium elements (reflectors) are present in the decommissioned research reactor which have been welded into steel capsules filled with Argon in 2 MOSAIC® type containers.

Finally, in France the presence of asbestos or mercury in its waste is no longer an issue insofar as asbestos is now accepted in disposal and a treatment to transform mercury into mercury sulphide (stable and non-toxic) is now available. However, for other toxic chemicals, French research is underway to develop appropriate immobilisation matrixes.

5.6 Preliminary analysis of the responses

Analysis of the responses provided by the questionnaire is expected to be done in two steps:

- Firstly, a preliminary analysis aims to summarize the main outputs which have started to be draft in Athens in March 2020 ;
- Secondly, a discussion between all the mandated actors based on the preliminary analysis will be organised, in order to identify the main challenging waste and the related issues that can be collaboratively tackled within the Joint Program and beyond (subtask 2.2).

This section provides the first analysis that can be drawn up from the results detailed in the section 5.4.

The analysis of the answers to the questionnaire and discussions at the Athens meeting shows that the reason why some wastes that are considering challenging are of different natures. It can be technical or organisational reasons; or even from a regulatory point of view.

In the response from the UK, a pie chart is included and summarizes the different reasons that can be attributed to considering a waste as challenging (see below, Figure 18). It turns out that the illustration presented by UK is a good summary of many of the situations that have been raised by the different MS. In the UK, 38% of waste is challenging due to a lack of a conditioning or treatment processes, 29 % due to a lack of a disposal options, and 14% due to a lack of characterization. Other reasons mentioned are related to organizational, regulatory, transport, retrieval and packaging issues.

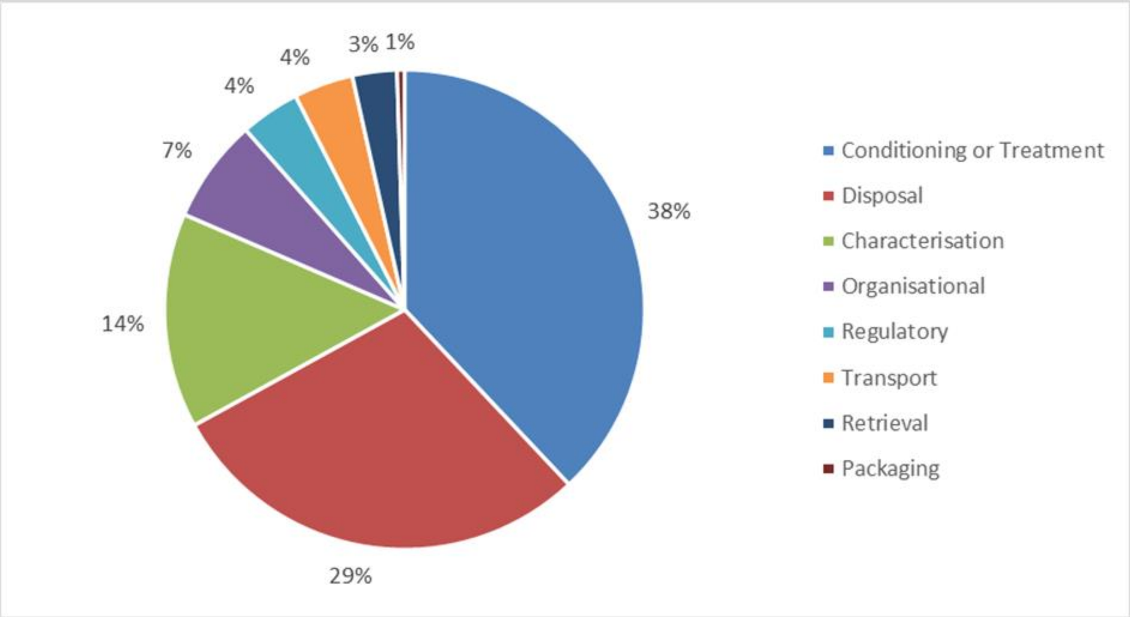

Figure 18: UK pie chart summarising the reasons to considerate waste as a challenging one

In general, radiological properties of challenging waste are important to guide their treatment and disposal options. It is clearly highlighted in the answers from many MS that a significant proportion of challenging waste has not yet been characterized to an extent that does not allow waste owners to define their management. Considering management decision making, the UK answer emphasizes the fact that although many wastes have not been characterized, they are nevertheless considered as challenging (for reasons other than the difficulty of characterization difficulty). **This is an anecdotal feedback to be stressed, namely that if the waste is perceived as having no waste route/management solution, there is no perceived benefit to prioritising characterization. Still, the lack of characterisation data can prevent identification of a waste route/management solution.**

To manage radioactive wastes, either their activity content or their chemical and toxic elements content have to be taken into account to define the management route. In some answers to the questionnaire, the issues of managing radioactive waste containing toxic elements and chemicals have been highlighted. This observation leads to a comparison of the different approaches between the disposal systems for hazardous waste and those associated with radioactive waste. **Often, in the countries, it turns out that the regulatory bodies differ between nuclear and chemical activities, without seeking any interaction with each other aiming to some harmonisations of practices. As a result, the regulations are different and sometimes not compliant with each other. This tricky question is not an R&D topic which can be addressed in this WP. Nevertheless, as ROUTES project is studying waste containing chemotoxic materials (e.g., beryllium, mercury; asbestos; lead), this issue should be tackled. . In that sense, ROUTES can insist on the fact that this existing gap between radiological and chemical safety assessment should be supported by international organizations such as IAEA, NEA or other organisations at EU level in other to initiate harmonization progresses.**

For some MS, the end state of the waste management strategy in the policy is not clearly defined and decisions about future disposal are postponed, and even these elements are mentioned in the EC directive, it is also clearly stated that the end state of waste management has to be disposal. For that reason, the "*wait and see strategy*" is the position taken by some organisations. Such a position allow them to avoid operations that lead to producing packages with characteristics that do not comply with WAC of a future disposal. In ROUTES, there is an opportunity to share between organisations the feedback of past operations that have been made in some MS. ROUTES Task 4 is more precisely dedicated on strategies aiming to manage waste without a defined disposal facilities. The concept of "no regret solution" will notably be explored within this task and this would be very enlightening and would help to improve the future of waste management. The lack of WAC mentioned as a reason for why some wastes are considered to be challenging will also be tackled by ROUTES Task 4. This will concern at least the characterization steps and more precisely, the radionuclides that are relevant to be measured for the long-term disposal safety. In the same way, some MS have mentioned that they have a *"Lack of, or poor knowledge of radioactive waste management for some challenging waste".* Sharing experiences in ROUTES between participants is precisely an opportunity to exchange knowledge and good practises on radioactive waste management. In addition, the defined topics could feed the training and knowledge management WP.

In section 4.2.2, it was emphasized that the Belgian example of categorization is a good example of waste management schemes. Indeed, it has been highlighted that this categorization can be developed step by step in order to define the routes for managing radioactive waste and try to answer to the question on how to deal with challenging waste. Producing such schemes in collaboration between the MS could help identify the R&D needs at each step. This work can be done in subtask 2.2. Using this example, it could be possible to build a template which could be helpful for the MS that do not have any clear schemes for waste management routes.

Finally, regarding the 'challenging waste' themselves, the questionnaires highlight that some waste are common to almost all the MS. Those waste are notably: spent ion exchange resins, disused sealed radioactive sources (DSRS), decommissioning waste, graphite and organic waste. Other waste like the ones containing reactive metals and chemotoxic substances have also been mentioned several time as challenging ones but only few information has been provided by the MS. In fact, it turns out that questionnaires have been filled out in a heterogeneous way. The discussions in Task 2.2 will allow for further exchange, harmonization and collection of more information, leading to provide a common list of challenging waste for which further R&D programs are needed. The subtask 2.2 will also provide the opportunity to further exchange with other ROUTES substasks (e.g., Subtask 4) as well as other EURAD projects like CORI or even the PREDIS or ERDO projects. The interactions among those projects will help to clearly identify the issues at stake, the new technics than can be developed and the clear needs for future research programmes.

6. Conclusions

This report provides a broad overview of the approaches that have been developed within the participating countries regarding the RW classification and categorization. An analysis of challenging waste streams specific to each country is also detailed in this report. The answers to the ROUTES questionnaire and the first exchange at the Athens meeting served as the input data for this report.

According to the responses obtained, there is no completely unified approach for RW classification in the participating countries. Various countries apply different types of RW classification, and sometimes several types of classification are used simultaneously in the same country. The IAEA GSG-1 approach to classification is somehow applied in the vast majority of participating countries. It should be mentioned that the classes "low level waste" and "intermediate level waste" do not always have the same meaning as in IAEA GSG-1, i.e. future disposal in near-surface disposal facilities and disposal facilities at intermediate depth, respectively. In many participating countries, low and intermediate level waste are combined as one class (LILW), which, in turn, is often subdivided into short-lived and long-lived RW. Generally, short-lived LILW could be associated with LLW within the meaning of IAEA GSG-1, whereas long-lived LILW could be associated with ILW within the meaning of IAEA GSG-1. However, such an interpretation is correct only in case that division of LILW into short-lived and long-lived is explicitly linked to the disposal route of this waste. This issue has not been clarified in many responses to the questionnaire.

Regarding categorization, less information is available from the responses to the questionnaire. At the ROUTES WP meeting in Athens, it was mentioned by many participants that different countries have a different understanding of RW categorization. The most comprehensive approach was presented by Belgium, which divides RW into unconditioned and conditioned, and then into respective subcategories. This approach could serve as an example of good practice for other participating countries.

Regarding challenging waste, the preliminary analysis made in this report on the nature and the reasons why some wastes are considered to be challenging, country by country, will be helpful for starting the further work in subtask 2.2. This subtask will notably aim to provide a detailed description of particular issues at stake in the different Member States for each challenging waste, taking into account pre-disposal and disposal steps. Based on this description, exchanges among Member-States and interaction with other research projects (EURAD/WPs like CORI or FuTURE, PREDIS, ERDO, etc.), will help to clearly define the future R&D needs that could help to better manage the challenging wastes in the future.

In conclusion, this report will serve as a good basis for the development of subtask 2.2 and notably for the analysis of the different approaches related to the management of challenging waste.

Appendix A. Answers to the Questionnaire related to RW classification and categorization (by country)

A.1 Austria (from National Report)

Radioactive waste is defined as radioactive material for which no further use is foreseen. Radioactive material means any substance that contains or is contaminated with one or more radionuclides with an activity or concentration that cannot be neglected, as far as radiation protection is concerned, and unless they are exempt from regulatory control. Exemption and clearance levels are laid down in the General Radiation Protection Ordinance. The nuclide specific values for clearance are derived from the internationally accepted concept of 10 µSv/year additional dose. Clearance measurements have to be certified directly or indirectly by the competent authority. Effective from 1st January 2004, NES adopted the Recommendation of 15th September 1999 on a classification system for solid radioactive waste 1999/669/EC, EURATOM. This radioactive waste classification system is based on the IAEA classification scheme (Safety Series No 111-G-1.1) GSG 1 and has been accepted by the regulatory body:

- Transition radioactive waste: Type of radioactive waste (mainly from medical origin) which will decay within the period of temporary storage and may then be suitable for management outside of the regulatory control system subject to compliance with clearance levels. Waste in the transition phase i.e. short-lived decay waste from medical applications containing 125 I is left to decay at the producers' sites, i.e., hospitals, or is brought to NES for decay storage.

- Low and intermediate level waste (LILW): In LILW, the concentration of radionuclides is such that generation of thermal power during its disposal is sufficiently low. These acceptable thermal power values are site-specific following safety assessments.

- Short-lived waste (LILW-SL): This category includes radioactive waste with nuclides half-life less than or equal to those of ^{137}Cs and ^{90}Sr (around 30 years) with a restricted alpha long-lived radionuclide concentration (limitation of long-lived alpha emitting radio-nuclides to 4000 Bq/g in individual waste packages and to an overall average of 400 Bq/g in the total waste volume). For classification purposes at NES internal waste-acceptance criteria for interim storage uses the limit of 400 Bq/g of long-lived alpha emitting radionuclides per waste package (instead of 4000 Bq/g per package).

- Long-lived waste (LILW-LL): Waste with alpha long-lived radionuclides whose concentration exceeds the limits for short-lived waste.

- High level waste (HLW): Waste with levels of activity concentration high enough to generate significant quantities of heat by the radioactive decay process or waste with large amounts of long lived radionuclides that need to be considered in the design of a disposal facility (is not arising in Austria).

A.2 Belgium

The ONDRAF/NIRAS waste classification is in line with the principles of the IAEA General Safety Guide “Classification of Radioactive Waste” (GSG-1, 2009). This means that it is based primarily on considerations of long term safety, and thus, by implication, disposal of the waste.

ONDRAF/NIRAS has a separate classification for conditioned waste and for non-conditioned waste.

Details of RW categorization in Belgium are presented in Section 4 of this Report.

As for classification with regard to the disposal route, conditioned RW belongs to category A if it is destined for the surface repository (planned to be constructed in the municipality of Dessel). Short-lived low active and short-lived medium active conditioned RW are a priori considered to belong to category A. Conditioned RW belongs to category B or C if its reference final destination is geological disposal.

Characteristic of conditioned RW belonging to category C is its high thermal power density, such that this has a major impact on the design of the repository. When comparing with the classification scheme in Figure 1 of GSG-1 (see above), category A corresponds with LLW, category B corresponds with ILW and category C corresponds with HLW. Since no specific final destination is planned for VLLW, the latter is included in category A.

A.3 Bulgaria

The classification of radioactive waste in Bulgaria is in accordance with the IAEA Safety Guide "Classification of Radioactive Waste" GSG-1. The Classification scheme of RAW, last changed 2013, is adopted with the Regulation for safe management of RAW and aimed at their long-term safe management and disposal. According with Art. 6 of the Regulation and depend of the activity and their specific characteristics, solid RAW is classified into:

Category 1 - waste containing radionuclides with low activity, which do not require the implementation of measures for radiation protection or do not need a high level of isolation and containment. These RAW are sub-divided into:

- ***category 1a*** – waste that meets the levels for release from regulatory control under the ASUNE;
- ***category 1b*** – very short-lived waste containing mainly radionuclides with short half-life (not more than 100 days), whose activity decreases below the levels for release from regulatory control as a result of appropriate storage on the site for a limited period of time (usually not more than several years);
- ***category 1c*** – very low level waste with levels of specific activity exceeding by a minimal value the levels for release from regulatory control under the ASUNE and with a very low content of long-lived radionuclides, which represent a limited radiological risk; for this category of waste, the application of specific measures for radiation protection or for isolation and containment is not required;

Category 2 – LLW and IMLW containing radionuclides in concentrations that require measures for reliable isolation and retention, but do not require special measures for heat removal during storage and disposal. These RAW are sub-divided into:

- ***category 2a –*** low-and intermediate level waste containing mainly short-lived radionuclides (with a half-life not longer than that of cesium-137) as well as long-lived radionuclides at significantly lower levels of activity, limited for the long-lived alpha- emitters under 4.106 Bq/kg for each individual package and a maximum average value for all packages in the respective facility of 4.105 Bq/kg; for such RAW reliable isolation and containment is required for up to several hundred years;
- ***category 2b*** – low-and intermediate level waste containing long-lived radionuclides at activity levels of long-lived alpha emitters, exceeding the limits of category 2a;

Category 3 – HLW with such a concentration of radionuclides in which heat removal must be taken into account during storage and disposal. For these RAW a higher level of isolation and containment compared to the LLW and IMLW is needed, through disposal in deep, stable geological formations.

This classification is also applies to liquid and gaseous RAW depending on the characteristics and waste form of the solid RAW that could be generated after the conditioning of liquid and gaseous waste.

In accordance with Art. 7 of the Radioactive Waste Management Ordinance, additional RAW sub-categories are introduced defined in the Procedure for Acceptance of RAW in the RAW Management Facility and these are used in Kozloduy NPP and State Enterprise Radioactive Waste (SERAW):

For solid RAW, depend of the gamma dose rate at a distance of 0.1 m from the surface**:**

- Category 2-I : 1μSv/h to 0.3 mSv/h;
- Category 2-II : 0.3 mSv/h to 10 mSv/h;

- Category 2-III: over 10 mSv/h.

For liquid RAW, depend of the **s**pecific beta activity**:**

- Category 2-L : up to 3,7.105 Bq/l
- Category 2-M: 3,7.105 Bq/l to 7,2.107 Bq/l
- Category 2-H: over 7,2.107 Bq/l.

**The above classifications does not take into account the non-radioactive hazardous constituents of the waste and their potential non radiological impact.*

A.4 Czech Republic

In agreement with the Decree No. 377/2016 Coll., on requirements for safe management of radioactive waste and decommissioning of nuclear installations or workplaces of category III or IV, RAW is categorized as gaseous, liquid and solid. Solid RAW is classified, particularly based on the method of disposal as follows:

- temporary radioactive waste, which after storage for at most 5 years exceeds radioactivity lower than clearance levels;
- very low-level waste with radioactivity higher than that of temporary radioactive waste, but which does not require any special measures during disposal;
- low-level waste with radioactivity higher than that of temporary radioactive waste, but which at the same time contains limited amounts of long-lived radionuclides;
- intermediate-level waste that contains a significant amount of long-lived radionuclides, and therefore it requires a higher degree of isolation from the surrounding environment than the low level waste; and
- high-level waste for which, during storage and disposal, it is necessary to take into account heat generated by decay of the contained radionuclides; the waste is processed and treated to meet the acceptance criteria and it must be disposed in deep geological repositories several hundred meters under the ground.

A.5 Cyprus

A national radioactive waste classification scheme has been adopted and supports the arrangements on the management of radioactive waste, taking fully into account the specific types and properties of radioactive waste. “Radioactive waste” for legal and regulatory purposes is defined as a material that contains or is contaminated with radionuclides at concentrations or activities greater than clearance levels as established by the existing legislation or as defined by the regulatory authority, and for which no use is foreseen. It should be recognized that this definition is purely for regulatory purposes, and that material with activity concentrations equal to or less than clearance levels is radioactive from a physical viewpoint, although the associated radiological hazards are negligible. Radioactive material which could meet the requirements for clearance, reuse, reprocessing or recycling is considered as potential radioactive waste, for example contaminated metal. Ownerless radioactive waste is radioactive waste where the generator no longer exists or cannot be identified through reasonable means or does not have the resources to manage such waste. Cyprus follows the guidelines of IAEA regarding the definition and classification of radioactive waste, as described in the General Safety Guide No. GSG-1 “Classification of radioactive waste”, IAEA, Vienna, 2009 [Ref. 5].

A.6 Denmark

DK only has a limited amount of RW and has no national classification scheme. In the Terms for Operation and Decommissioning, issued by the Regulator, it is mentioned that Dekom is obliged to follow the classification scheme of IAEA GSG-1.

A.7 France

The system in France splits the waste into 5main categories based on the specific activity of the waste package and the half-life of the radionuclides:

1. TFA: Très Faible Activité or Very Low Level Waste (VLLW) - The level of activity is typically below 100 Bq/g;

2. FA-VC: Faible Activité (FA) à Vie Courte, or Short Lived Low Level (LLW-SL) The radioactive level of these wastes is usually between 10^2 and 10^5 Bq/g and have a half-life of ≤31 years;

MA-VC:Moyenne Activité (MA) à Vie Courte, or Short Lived Intermediate Level (ILW-SL). The radioactive level of these wastes is usually between 10^2 and 10^6 Bq/g and have a half-life of ≤31 years. Both FA-VC and MA-VC wastes have the same disposal route and are also known as LILW-SL

3. FA-VL: Faible Activité à vie longue or Long Life Low LevelWaste (LLW-LL). The level of activity of these wastes is usually between 10^2 and 10^5 Bq/g and have a half-life >31years.

4. MA-VL:Moyenne Activité à Vie Longue or Long Lived Intermediate LevelWaste (ILW-LL). The activity of these wastes is usually between 10^6 and 10^9 Bq/g;

5. HA: Haute Activité or High Active. The activity of these wastes is >10^9 Bq/g

The management routes according to each category is given in the table below:

		Very short lived waste containing radionuclides with a half-life of < 100 days	Short lived waste in which the radioactivity comes mainly from radionuclides with a half-life ≤ 31 years	Long lived waste containing mainly radionuclides with a half-life > 31 years
Hundreds Bq/g	Very low level (VLL)	**Management by radioactive decay on the production site**	***Recycling or dedicated surface disposal*** *(disposal facility of the Industrial centre for collection, storage and disposal in the Aube département)*	
	LOW LEVEL (LL)	*then disposal through routes dedicated to conventional waste*	***Surface disposal*** *(Aube waste disposal repository)*	***Subsurface disposal*** *(studied pursuant to the 28th June 2006 Act)*
Millions Bq/g	Intermediate level (IL)			
Billions Bq/g	High level (HL)	**Not applicable** *The category high level, very short-lived waste does not exist*	***Deep geological disposal*** *(planned pursuant to the 28th June 2006 Act)*	

A.8 Germany

In Germany, disposal in deep geological formations is planned for all types of radioactive waste. Accordingly, there is no need to differentiate between waste containing radionuclides with comparatively short half-lives and waste containing radionuclides with comparatively long half- lives. Therefore, the definition and categorization of radioactive waste must meet the waste acceptance requirements for the underground repository. In this respect, the effects of heat generation from radioactive waste on the design and evaluation of a repository system are particularly important, since the natural temperature conditions may be significantly altered by the waste emplaced. In accordance with the German approach to disposal, radioactive wastes are subjected to a subdivision into:

- heat-generating waste and
- waste with negligible heat generation.

Heat-generating radioactive waste is characterized by high specific activity and thus high decay heat and includes, in particular, vitrified wastes, hulls and structural components from spent fuel reprocessing, and spent nuclear fuel to be disposed of directly. Wastes with negligible heat generation contain distinctively lower specific concentrations encompassing wastes from the operation, decommissioning and dismantling of nuclear facilities (e.g. disused plant components, ion exchange resins, air filters, cleaning agents, contaminated/activated concrete structures) and/or from the application of radioisotopes. According to National program of Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety ca. 60% of all waste with negligible heat generation originates from nuclear industry, 37% - from research activities and ca. 3% - from the healthcare sector.

A.9 Greece

The classification schemes of radioactive waste in Greece is based on the methodology of the International Atomic Energy Agency (IAEA). Thus, radioactive waste in Greece is classified as VSLW, VLLW, LLW and in small quantities ILW. The distinction between very short lived and long lived radioactive waste is based on the half-life values of 100 days and 30 years, respectively. There aren't HLW in the country.

Furthermore, RW are classified according their origin, type and management options to the following categories:

a. Solid and liquid RW originated from the past activities and operation of the GRR-1 research reactor and RW from the decommissioning of the GRR-1. Examples include resins, sediments, historical waste, activated and contaminated objects. The characterization of this RW is ongoing. However, RW is estimated to be VLLW, LLW and in small quantities ILW. The disposal option is in an engineered near surface disposal facility and / or in a surface trench or in a borehole.

b. Disused sealed radioactive sources (DSRS), orphan sources and radioactive objects temporarily stored at their holders' premises, including the NCSR "Demokritos" radioactive waste management facility, and which cannot be exported to a recycling facility. The expected option of disposal is in an engineered near surface disposal facility or in a borehole.

c. Radioactive materials and consumer products, such as radioactive lighting rods, smoke detectors, devices with fluorescent materials. The expected mode of disposal is in an engineered near surface disposal facility or in a borehole.

d. RW resulting from the decommissioning of the GRR-1 research reactor and other facilities (isotope production circulators). RW is expected to be VLLW, LLW and in small quantities ILW. The preferred disposal option is in an engineered near surface disposal facility and in a surface trench or in a borehole

A.10 Hungary

- Very low level waste:
    - For isotopes with lower half-life than 30yrs: $\sum_i \frac{AC_i}{SEAL_i} \leq 50$ (SEAL: Specific Exemption Activity Level)
    - For isotopes with longer half-life than 30 yrs: $\sum_i \frac{AC_i}{GEAL_i} \leq 1$ (GEAL: General Exemption Activity Level)
- Low level waste: $\sum_i \frac{AC_i}{SEAL_i} \leq 1000$
- Intermediate level waste: $\sum_i \frac{AC_i}{SEAL_i} > 50$
- High level waste: Heat generation greater than 2 kW/m^3
- Long-lived waste: half-life greater than 30 yrs.

A.11 Lithuania

RAW Classification system in Lithuania highly correspond to IAEA classification system:

RW classification	Definition (abbreviation)	Surface dose rate, mSv/h	Conditioning	Disposal method*
0	Exempt waste (EW)	-	Not require	Management according to BSR-1.9.2-2011 requirements
Short lived very low, low and intermediate level waste**				
A	Very low level waste (VLLW)	<0.2	Not require	VLLW repository
B	Low level waste (LLW-SL)	0.2-2	Require	Near surface repository
C	Intermediate level waste (ILW-SL)	>2	Require	Near surface repository
Long lived low and intermediate level waste***				
D	Low level waste (LLW-LL)	<10	Require	Near surface repository (cavities at intermediate depth)
E	Intermediate level waste (ILW-LL)	>10	Require	Deep geological repository
High level waste				
G	High level waste (HLW)	-	Require	Deep geological repository
Spent sealed sources				
F	Spent sealed sources (SSS)		Require	Near surface or deep geological repository****

* The method of disposal at the repository is determined by the compliance of the radioactive waste packages with the WAC for a specific radioactive waste repository.

** Containing beta and/or gamma emitting radionuclides with half-lives less than 30 years, including Cs137, and/or long lived alpha emitting radionuclides with measured and/or calculated, by using approved methods, activity concentration less than 4000 Bq/g in individual waste packages on condition that an overall average activity concentration of long lived alpha emitting radionuclides is less than 400 Bq/g per waste package.

*** Containing beta and/or gamma emitting radionuclides with half-lives more than 30 years, not including Cs137, and/or long lived alpha emitting radionuclides with measured and/or calculated, by using approved methods, activity concentration more than 4000 Bq/g in individual waste packages on condition that an overall average activity concentration of long lived alpha emitting radionuclides exceeds 400 Bq/g per waste package.

**** Depending on acceptance criteria applied to spent sealed sources.

A.12 Netherlands

In the Netherlands, radioactive waste is divided into four categories:

- high level radioactive waste,
- low level and intermediate level radioactive waste (including NORM waste),
- short-lived waste and
- exempt waste.

These categories are based on activity and half-life.

A.13 Poland

In Poland, management of the radioactive waste is regulated by the Act of Parliament of 29 November 2000 on the Atomic Law, which is implemented basing on the recommendations of the International Commission of Radiological Protection (ICRP), Directions of the Council of the European Union and the Recommendations of the International Atomic Energy Agency. The document, the last update being in force since September 23, 2019, classifies radioactive waste by activity as low, medium and high active. An additional division into sub-categories was established:

- transitional waste - if the radioactive concentration of isotopes in the waste at the time it is generated is so, that over a period of 3 years will decrease to the value smaller than the values specified for low-level waste;

- short-lived waste – if they contain:

a) short-lived radioactive isotopes, and

- average radioactive concentration of long-lived isotopes in this waste does not exceed 400 kBq/kg; -
- maximum radioactive concentration of long-lived isotopes in this waste, resulting from the heterogeneity of the material in a representative 1 kg sample of waste, does not exceed 4000 kBq,

b) only long-lived radioactive isotopes, and the average radioactive concentration of these isotopes in the waste does not exceed 400 kBq/kg

- long-lived waste - if the average radioactive concentration of long-lived isotopes in this waste exceeds 400 kBq/kg

Disused sealed radioactive sources are classified according to the concentration of their radioactivity:

- low-level – if the activity of their isotopes does not exceed the value of 10^8 Bq;
- intermediate level - if the activity of their isotopes exceeds 10^8 Bq but does not exceed 10^{12} Bq;
- high level - if the activity of their isotopes exceeds the value of 10^{12} Bq.

A.14 Portugal (from National Report)

As it is stated in the National Report by Portugal for the 6th Review Meeting for Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management: “Categorization of radioactive waste is included in the National Program, as specified in the International Atomic Energy Agency’s standards”.

At the moment, RW classification in Portugal is as follow:

<table>
<tr><th>Classification</th><th>Very Short Lived
$T_{1/2} < 100$ d</th><th>Short Lived
$T_{1/2} < 31$ y</th><th>Long Lived
$T_{1/2} > 31$ y</th></tr>
<tr><td>VLLW</td><td>Decay at the producers</td><td colspan="2">Decay at interim storage facility, with possible future liberation or deposition in dangerous materials landfill</td></tr>
<tr><td>LLW</td><td rowspan="2">Clearance</td><td>Decay at interim storage facility, with possible future liberation</td><td>Decay at interim storage facility</td></tr>
<tr><td>ILW</td><td colspan="2">Decay at interim storage facility</td></tr>
</table>

A.15 Romania

According to the national regulation, the general classification of radioactive waste is the following:

- excepted radioactive waste (EW): RW containing radionuclides with an activity concentration so small that the waste can be released from regulatory control (conditionally or unconditionally);
- transitional radioactive waste (TW): RW having activity concentration above clearance levels, but which decays below clearance levels within a reasonable storage period (not more than 5 years);
- very low-level radioactive waste (VLLW): RW in which the activity concentration is above the clearance levels, but with a radioactive content below levels established for defining the low-level waste;
- low and interim level short lived radioactive waste (LILW-SL);
- low and interim level long lived radioactive waste (LILW-LL).

  LILW is RW in which the activity concentration is above the levels established for the definition of VLLW, but with a radioactive content and thermal power below those of high-level waste. Low level waste does not require shielding during handling or transportation. Intermediate level waste generally requires shielding during handling but needs little or no provision for heat dissipation during handling or transportation. The long-lived radioactive waste is a waste containing radionuclides with half-life above 30 years in quantities and/or concentrations of activity above the values established for which isolation from biosphere is necessary for more time than the institutional control duration. The short-lived radioactive waste is a radioactive waste that is not long lived

- high level radioactive waste (HLW) – this category refers mainly to the spent fuel that in Romania is considered radioactive waste

The general classification refers to the requirements for assuring the isolation from biosphere of the radioactive waste during its disposal. The LILW-SL can be disposed of in near surface disposal facilities, while the disposal of VLLW requires less complex arrangements than the disposal of short lived low level waste. The LILW-LL and HLW have to be disposed of in deep geological facility.

Different operational classification scheme is applied at Cernavoda NPP for operational waste sorting, pre-treatment, treatment (incineration and melting at international waste operators) and storage. The operational classification of RW is performed taking into account: origin and types of the waste, nuclear and radiological properties, management options, and other properties.

A.16 Slovakia

RAW classification according to their activity level is based on the mode of its disposal. Classification is stated in Nuclear regulatory authority (NRA) Regulation No. 30/2012 Coll. and it is fully consistent with IAEA RAW classification. According to activity level, radioactive waste is divided into following classes:

- **Transient radioactive wastes** whose activity falls below the limit value for their introduction to the environment) during storage.
- **Very low level radioactive waste (VLLW)**, whose activity is slightly higher than the limit value for their introduction to the environment, contains mainly radionuclides with a short half-life, or also a low concentration of radionuclides with a long half-life, and which during storage requires a lower degree of isolation from the environment through a system of engineered barriers as in the case of surface-type radioactive waste repositories.
- **Low level radioactive waste (LLW)**, whose average specific activity of radionuclides with a long half-life, especially radionuclides emitting alpha radiation, is less than 400 Bq/g, maximum specific activity of radionuclides with a long half-life, especially radionuclides emitting alpha radiation, is locally less than 4000 Bq/g, does not produce residual heat, and following treatment meets safe operating limits and conditions for surface-type radioactive waste repositories.
- **Intermediate level radioactive waste (ILW)**, whose average specific activity of radionuclides with a long half-life, especially radionuclides emitting alpha radiation, is equal to or over 400 Bq/g, may produce residual heat and measures for its removal are less than in the case of high level radioactive waste, and which following treatment does not meet safe operating limits and conditions for surface-type radioactive waste repositories.
- **High level radioactive waste (HLW)**, whose average specific activity of radionuclides with a long half-life, especially radionuclides emitting alpha radiation, exceeds values specified for low-activity radioactive waste requiring measures for the removal of residual heat and can be deposited only in an underground-type radioactive waste repository meanwhile measures for removal of residual heat is an important factor in designing these disposal facilities.

Waste arising from controlled area (CA) and from all workplaces beyond CA generating radioactive waste is managed according to its activity level as consistent with above mentioned classification:

Transient RAW that is temporary stored until its activity meet the limit value for its release to the environment. Majority of radionuclides contained in these waste has half-life of some hundreds of days (approximately up to 5 years), therefore it is reasonable to store it and consequently release it into the environment after activity decrease.

A.17 Slovenia

Rules on radioactive waste and spent fuel management (JV 7, Off. Gaz.49/2006) lay down the classification of radioactive wastes according to level and type of radioactivity in Slovenia.

In JV7, article 4 the RW classification is given as:

(1) Depending on its aggregate state, radioactive waste is classified as solid, liquid or gaseous.

(2) Solid radioactive waste is classified into the following categories, according to level and type of radioactivity:

1. transitional radioactive waste[4];
2. very low-level radioactive waste (hereinafter referred to as VLLW), for which the regulatory authority competent for nuclear and radiation safety (hereinafter referred to as Administration) may decide on clearance;
3. low- and intermediate-level radioactive waste (hereinafter referred to as LILW), in the management of which heat generation does not need to be considered; it is further classified into two groups:
   3.1. short-lived LILW, where the specific activity of the contained alpha emitters, having a half-life exceeding 30 years, is equal to or lower than 4000 Bq/g in any individual package but in no case greater than 400 Bq/g on average in the overall amount of LILW;
   3.2. long-lived LILW, where the specific activity of alpha emitters exceeds the limitations applying to short-lived LILW;
4. high-level radioactive waste (hereinafter referred to as HLW), which contains radionuclides, the decay of which generates such an amount of heat that has to be considered in its management;
5. radioactive waste containing naturally occurring radionuclides that are produced in the exploitation and reprocessing of nuclear mineral raw materials or in other industrial processes and are not considered sealed sources of radiation pursuant to the regulation governing the use of radioactive sources and radiation practices.

A.18 Spain

- Very Low Activity Level Radioactive Waste (short and medium half-life).(RBBA)
- Very low Activity Level Radioactive Waste (long half-life).(RBBA)
- Low and Medium Activity Level Radioactive Waste (short and medium half-life).(RBMA)
- Low and Medium level Radioactive Waste (long half-life).(RBMA)
- High Activity Level Radioactive Waste (RAA)

The classification takes into account the initial activity of the waste and the half-life of the macro components radionuclides, which can be short and half-lived (less than 30 years), or long-lived when their half-life is longer than this value.

The following table (included in the 4th national report of the Joint Convention) shows the classification of radioactive waste in Spain with its already operational or planned management routes.

[4] Transitional radioactive waste means radioactive waste for which in less than five years of decay-storage or storage, the level of specific activity of radionuclides contained decreases to a level at which the holder, in accordance with the regulation governing radiation practices, applies the clearance of radioactive waste.

INITIAL ACTIVITY	**HALF LIFE**	
	Short and Medium Life Main Nuclides < 30 y.	Long Life Main Nuclides > 30 y.
Very Low Level VLLW	Surface Repository: C.A. ENRESA "EL CABRIL"	In situ Stabilization in mining sites
Low and Intermediate Level (L&ILW)	Surface Repository: C.A. ENRESA "EL CABRIL	Expected in Centralized Temporary Storage (CTS).
High Level Waste (HLW	Storage "on site" individualized temporary Storage (ITS) Expected in CTS	

The so-called radioactive wastes of very low activity [VLLW (short and medium life)] could be defined as a subset of the previous ones when they only reach activity concentrations of the order of 10 to 1000 Bq / g. In Spain, since 2008 a differentiated final management has been established through final storage systems appropriate to the radiological risk they pose.

The radioactive waste of very low activity [VLLW (long life)] generated in Spain comes from mining activities and the manufacture of uranium concentrates and contains radionuclides from the decay chains of uranium (238) and thorium (232), which generally have periods very high half-lives. In Spain, the management of this type of radioactive waste is carried out to date by stacking and stabilization in situ at the production facilities themselves.

The so-called radioactive wastes of low and medium activity [L&ILW (short and medium life)] are those whose activity is mainly due to the presence of radionuclides with a short or medium half-life (less than 30 years), and whose content of long-lived radionuclides is very low and limited.

The so-called high-activity radioactive wastes [HLW] are those that contain long-lived alpha emitters, with a half-life of more than 30 years, in appreciable concentrations and can generate heat as a result of radioactive decay, since their specific activity is high. The main exponent of this waste is spent fuel discharged from nuclear reactors. Additionally, for integral management purposes, this set includes those other Medium Activity wastes that, due to their characteristics, are not capable of being managed in a final way under the conditions established for "El Cabril" and specific needs for this. The temporary solution for all this set of radioactive waste will consist of its storage in the Centralized Temporary Storage (CTS).

Special Waste (SW), This includes the attachments of nuclear fuel, neutron sources, used intranuclear instrumentation or replaced components from the reactor vessel system and internal components from the reactor, generally metallic, that present a high radiation dose from the neutron activation, and all those wastes that, according to their radiological characteristics, cannot be disposed of in the existing Surface Disposal Facility in Spain, C.A. El Cabril [Instruction IS-29 of CSN]. Their management is associated to High Level Waste

Radium sources, Lighting rods and smoke detectors has an special management routes depending of the half-life, activity content and nuclides to be treated.

NORM Waste (Naturally Occurring Radioactive Materials)) a specific Ministerial Order regulates the management of these wastes. In line with the aforementioned Order, it is necessary for producers of this type of waste to carry out certain prior actions:

- The radiological characterization of the waste to determine that is or is not lower than the declassification levels.
- If the radioactive content is less than or equal to the declassification levels, the waste may be managed through the usual conventional channels, in accordance with the applicable legal regulations.

Radioactive waste can also be classified according to other criteria: according to its origin, its physical state (liquid, solid or gaseous), its properties (compactable / non-compactable, burnable / non-burnable, metallic…).

Source: Monografy about Radioactive Waste of CSN: (https://www.csn.es/clasificacion-de-residuos-radiactivos

A.19 Sweden

	Free release	SL VLLW	SL LLW	SL ILW	LL LILW	SNF
Definition		Dose rate < 0,5 mSv/h	Dose rate < 2 mSv/h	Dose rate < 500 mSv/h	Significant content of LL nuclides	Significant content of LL nuclides and produces heat energy

A.20 Ukraine

At the moment, RW classification in Ukraine is as follows.

Depending on the goals of classification, RW are classified by types, groups, categories and kinds:

1. **Types –** two types of RW:
    a. short-lived are acceptable for disposal in the near-surface disposal facilities;
    b. long-lived are required to be disposed of in stable deep geological formations.
2. **Groups –** four groups of RW by the level for clearance from the regulatory control:
    a. Group 1 includes transuranium alpha-emitting radionuclides – 0.1 Bq/g;
    b. Group 2 includes alpha-emitting radionuclides (except for transuranium) – 1 Bq/g;
    c. Group 3 includes beta-gamma-emitting radionuclides – 10 Bq/g;
    d. Group 4 includes H-3, C-14, Cl-36, Ca-45, etc. – 100 Bq/g.
3. **Categories –** by the criterion of specific activity. HLW are divided into two subcategories: low-temperature (where specific heat release does not exceed 2 kW/m^3) and heat-generating (where specific heat release exceeds 2 kW/m^3)

In 2019, changes were introduced to the Ukrainian legislation (Law of Ukraine "About Radioactive Waste Management". Instead of two types of RW, four RW **classes** are established:

- very low level waste (VLLW),
- low level waste (LLW),
- intermediate level waste (ILW) and
- high level waste (HLW)

depending on acceptability for disposal in one of four types of disposal facilities: surface, near-surface, disposal facilities at intermediate depth and deep geological repository. These changes will be put into force in 2021.

According to the Ukrainian regulatory document NP 306.4.219-2018 «General safety provisions for radioactive waste disposal», following definitions of types of RW disposal facilities are provided:

"Surface-type disposal facility is organized in a structure, trenches, or at the ground surface including barriers capable of containing and isolating RAW during the period of time of not less than 100 years after disposal facility closure;

Near-surface type disposal facility is organized on the ground surface or near-surface soil layer (at the depths of up to several dozen meters) including the barrier system capable of containing and isolating RAW in the period of time of not less than 300 years after the disposal facility closure;

Disposal facility at intermediate depth is organized at the depth in the range from several dozen to several hundred meters including the barriers system capable of containing and isolating RAW in the period of time of not less than several thousand years after disposal facility closure;

Geological-type disposal facility is organized in the deep geological formations characterized by the predictable geological conditions (at the depth of several hundred meters and more from the ground surface) including the barrier system capable of containing and isolating the RAW for the long-time period following disposal facility closure, taking into consideration the thermal emission resulting from radionuclides natural decay.

Disposal facility type should be selected based on the characteristics of the RW subject to disposal (radiological, physical, chemical and thermal), given the natural conditions of the disposal facility site location".

A.21 UK

In the UK, radioactive wastes are classified according to the type and quantity of radioactivity they contain and how much heat is produced:

- Lower Activity Waste (LAW), which comprises:
    - Low Level Waste (LLW) (<4 GBq t-1 α , <12 GBq t-1 βγ (~94% by volume of the 2019 UK's Radioactive Waste Inventory (UKRWI)),
    - Very Low Level Waste (VLLW); a sub-category of LLW that can be disposed of to permitted landfill facilities. VLLW is normally regarded as material with a specific activity up to 200Bq/g, often referred to in the industry as Low Activity Low Level Waste (LA-LLW), although this is not a formal classification. See:

      https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/692547/WSC-Guidance-V-001-_-Issue-1-_-May-2017-FINAL.pdf

      VLLW includes:

        - High Volume VLLW – wastes with a maximum concentration of 4 MBq t^{-1} total activity (there is an additional limit for tritium) which can be disposed of to specified landfill sites
        - Low Volume VLLW – wastes that can be safely disposed of to an unspecified destination with municipal, commercial or industrial waste; each 0.1 m^3 of material containing <400 kBq of total activity, or single items containing <40 kBq of total activity (there are additional limits for C-14 and tritium)
- Higher Activity Waste (HAW), which includes:
    - High Level Waste (HLW) (<1% by volume of the 2019 UKRWI) – wastes in which the temperature may rise significantly as a result of their radioactivity, such that this factor has to be taken into account in the design of storage or disposal facilities,
    - Intermediate Level Waste (ILW) (~6% by volume of the 2019 UKRWI) – wastes exceeding the upper boundaries for LLW, but which do not generate sufficient heat for this to be taken into account in the design of storage or disposal facilities,
    - Some LLW that is unsuitable for disposal in the Low Level Waste Repository (LLWR).

It is notable that, unlike waste classification schemes in many countries, UK waste categories do not distinguish between wastes containing predominantly short-lived and long-lived radionuclides. There has been some consideration of alternative approaches. For example, a report commissioned by LLW Repository Ltd in 2016 compared different national waste classification approaches, and identified generic approaches, as a basis for informing discussion in the UK on whether there could be benefits from adapting the national approach to waste classification:

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/697667/NWP-REP-134-International-Approaches-to-RW-Classification-Oct-2016.pdf.

References

(GSG-1) Classification of Radioactive Waste. General Safety Guide No. GSG-1. IAEA, Vienna, 2009

(Joint Convention) Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management.

(TECDOC-1538) IAEA-TECDOC-1538. Categorizing Radioactive Waste. IAEA, Vienna, 2007