Deliverable 2.4
International approaches to establishing a waste acceptance system

31.08.2021, version Final

Dissemination level: Public

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This project has received funding from the Euratom research and training programme 2019-2020 under grant agreement No 945098.

Project acronym PREDIS	Project title PRE-DISposal management of radioactive waste		Grant agreement No. 945098
Deliverable No. D2.4	Deliverable title International approaches to establishing a waste acceptance system		Version Final
Type Report	Dissemination level Public		Due date M12
Lead beneficiary CV Rez			WP No. 2
Main author Lumir Nachmilner, CV Rez	Reviewed by Ferenc Takats, TS ENERCON	Accepted by WP 2 Leader	
Contributing author(s) T 2.3 Partners: ENRESA (ESP), FMTC (LIT), GSL (UK), ISOTOPTECH (HU), SCK CEN (BEL), SI IEG NASU (UKR), SOGIN (IT), SÚRO (CZ), TSE (HU), TUS (BUL), VTT (FIN)			Pages 74

Abstract

The report summarises information collected by Task 2.3 Partners regarding the waste acceptance systems in 29 countries worldwide. The focus is on the assessment of inputs for the development of other subsequent Task 2.3 deliverables, namely a critical review of conditioned waste characterisation methods, guidance for the qualification of conditioned waste forms for disposal, and guidance on the derivation of generic waste acceptance criteria. Cooperative efforts with other international projects dealing with waste acceptance area also reported.

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Acknowledgement

This project has received funding from the Euratom research and training programme 2019-2020 under grant agreement No 945098.

HISTORY OF CHANGES

Date	Version	Author	Comments
14.04.2021	Template	CV Rez	
28.05.2021	Draft 1	CV Rez	
24.06.2021	Draft 2	CV Rez	
24.07.2021	Draft 2.1	CV Rez	
02.08.2021	Draft 2.2	CV Rez	
19.08.2021	Final 1	CV Rez	
25.08.2021	Final 2	CV Rez	
31.08.2021	Final 3	CV Rez	

TERMS USED IN THE FOLLOWING TEXT:

Waste acceptance system *(the IAEA uses the term 'WAC')* – the overall set of requirements on a waste form, input materials used during waste processing, and a waste package applied during the management of radioactive waste (RWM); it includes acceptance criteria for all RWM stages as well as parameters qualifying a waste form for disposal.

Waste acceptance criteria – selected parameters to be checked on receipt of waste from the previous step of RWM (collection → processing → storage → disposal).

A waste acceptance criterion consists of three elements: **a parameter, its value, and a method** of its determination (measurement or substantiation or demonstration).

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1 INTRODUCTION

A waste acceptance system (WAS), as considered and applied in the PREDIS Project, consists of two basic elements: (a) the assessment of suitability of the final waste form for storage & disposal (waste form qualification – WFQ) including an extensive set of tests and/or proofs of performance in future anticipated conditions, and the description of chemical, physical and biological characteristics of the final waste form, and (b) criteria to be demonstrated in the process of the hand-over of waste in particular stages of the radioactive waste management (RWM) process, namely while accepting a waste package into storage and disposal facilities (waste acceptance criteria – WAC).

The overall objective of Task 2.3 of PREDIS Work Package 2 (WP2) on Strategic Implementation is to provide a critical review of conditioned waste characterisation methods, including non-radiological techniques, and to compile guidance documents (i) for the qualification of conditioned waste forms for disposal, and (ii) on generic waste acceptance criteria and their derivation based on proven practices. The task places a focus on the application of this knowledge to small inventory and developing disposal programmes, however, its findings might be considered while updating WASs of more advanced RWM programmes as well.

The Task was formulated with respect to ongoing international projects addressing WAS/WAC issues: it intends to elaborate problems which have not been incorporated in the Agenda of these projects to complete the spectrum of relevant information. Furthermore, the main outputs of the Task should provide advice on predisposal phases of the waste management lifecycle, in particular on planning and implementing waste processing technologies, for national programmes missing disposal capacities. It is believed that guidance documents generated by this Task would enhance decision making process for ensuring safe management of low and intermediate level waste.

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

This report assesses the extent to which the information collected provides inputs for the planned Deliverables described below. The quality of the completed information is briefly assessed in the following sections which also include summaries of information gathered in the first phase of the project.

Deliverable 2.5 Waste form characterisation

Knowledge of the radionuclide and chemical inventory of waste to be disposed of (including metallic and organic compounds) is important for the transport, pre-operational and operational activities, and safety case of the facilities. There are numerous methods developed for the determination of physical and chemical parameters, quantification of non-radiological features of the waste forms/waste packages, and determination of activity of difficult to measure isotopes.

This subtask will assess these methods from the point of view of their effectiveness, considering safety, technical and economic aspects. Recommendations will be provided for selecting economically viable methods ensuring the necessary extent and quality of information on waste form performance.

Deliverable 2.6 Waste form qualification

Based on the information collected, the expert team will assess national approaches, practices, and requirements regarding the waste form qualification process and outline a guide on providing evidence that a considered waste form is suitable for disposal. This guide will consider typical disposal options for low and intermediate level waste (i.e., near surface and subsurface facilities). The application of the qualification process will be tested on selected waste forms developed in the technical work packages WP4-7 of the PREDIS project.

Deliverable 2.7 Guidance on formulating generic waste acceptance criteria

A necessary aspect of the safety measures required while commissioning a disposal facility is the formulation of limits and conditions for its operation. These formulations include a set of waste acceptance criteria used for the verification of the compliance of waste packages delivered by waste producers to the disposal facility based on safety, technical and administrative requirements. However, even if a disposal infrastructure is missing, waste producers need some instructions for the selection and application of waste conditioning technologies for waste streams to be disposed of in the future in order to at least preliminarily handle the waste. In this case, such instructions can be formulated as generic waste acceptance criteria (G-WAC).

Planned guidance on the formulation of a typical G-WAC set which might be applied in national programmes without disposal facilities, will draw from collected national analyses and experience of the involved organisations.

2 SUMMARY OF COLLECTED INFORMATION

2.1 Waste acceptance system

The waste acceptance system consists in the formulation of requirements for taking custody of wastes in particular phases of their management. It includes the following elements:

- ***Predisposal waste acceptance criteria*** are based on technological requirements of RW processing technologies. The main criteria linked to disposal are activities of important radionuclides contained in the waste and the presence of toxic, corrosive, flammable, or otherwise hazardous species requiring specific treatment procedures.
- ***Acceptance criteria for taking custody over final waste forms at storage and/or disposal facilities*** consist of three elements, (i) a parameter to be followed, (ii) its value, and (iii) a method for its measurement and demonstration. The goal of D2.5 is providing advice on the selection of measuring techniques for typical WAC parameters with consideration of their feasibility for small RWM programmes based on technical and economical assessment of their application.
- ***The waste form qualification process*** brings the evidence that a selected waste form is acceptable for a disposal facility. This evidence shall preferably address the characterisation of long-term performance of the final waste form (including its package, if applicable) in anticipated disposal conditions. It also provides inputs to predisposal WAC (parameters to be checked and controlled to ensure the required quality of the selected waste form and package). This issue is to be addressed in D2.6 (see the previous Chapter 1).

An entire set of WACs can be defined after relevant parameters of a disposal facility have been determined (i.e., designed and sited, optimally built) and its safety case elaborated. However, it is vital for countries without disposal facilities to define requirements on waste forms generated now with the perspective of their disposal in the future. Deliverable 2.7 will include instructions on how to define generic WAC so that they would be compatible with a disposal facility once it has been developed.

Figure 1 indicates which elements of the waste acceptance system will be addressed in Task 2.3 Deliverables (yellow highlighted).

2.2 Collection of information

The main goal of activities performed in the first year of the project implementation was to collect information from national RWM programmes regarding the data needed for the three planned guidance deliverables mentioned above. This document is not intended to exhaustively describe waste acceptance systems in countries selected for the analysis, rather it has focused on Deliverable topics. The document also includes a preliminary assessment, prepared by managers of relevant subtasks, i.e., ISOTOPTECH, SÚRO, and TSE ENERCON, of the sufficiency of the collected data for the development of Task Deliverables. Summaries of PREDIS webinars prepared by VTT were the main inputs used for the section regarding collaboration with external projects.

The input national analyses were prepared by all Task 2.3 partners and also deal with some countries outside the EU. Information was retrieved mostly using public sources, relevant national programs and documents, personal contacts, IAEA documents, and data from other EC projects dealing with WAC. We decided to avoid a form of questionnaire which was not considered as an effective tool for our purposes (two-thirds of the investigated countries were not represented in our Task). The national analyses are ‘living’ documents and might be revised and updated during the Task implementation; any new information relevant to the planned Deliverables might be used by the expert team up to the point they are issued.

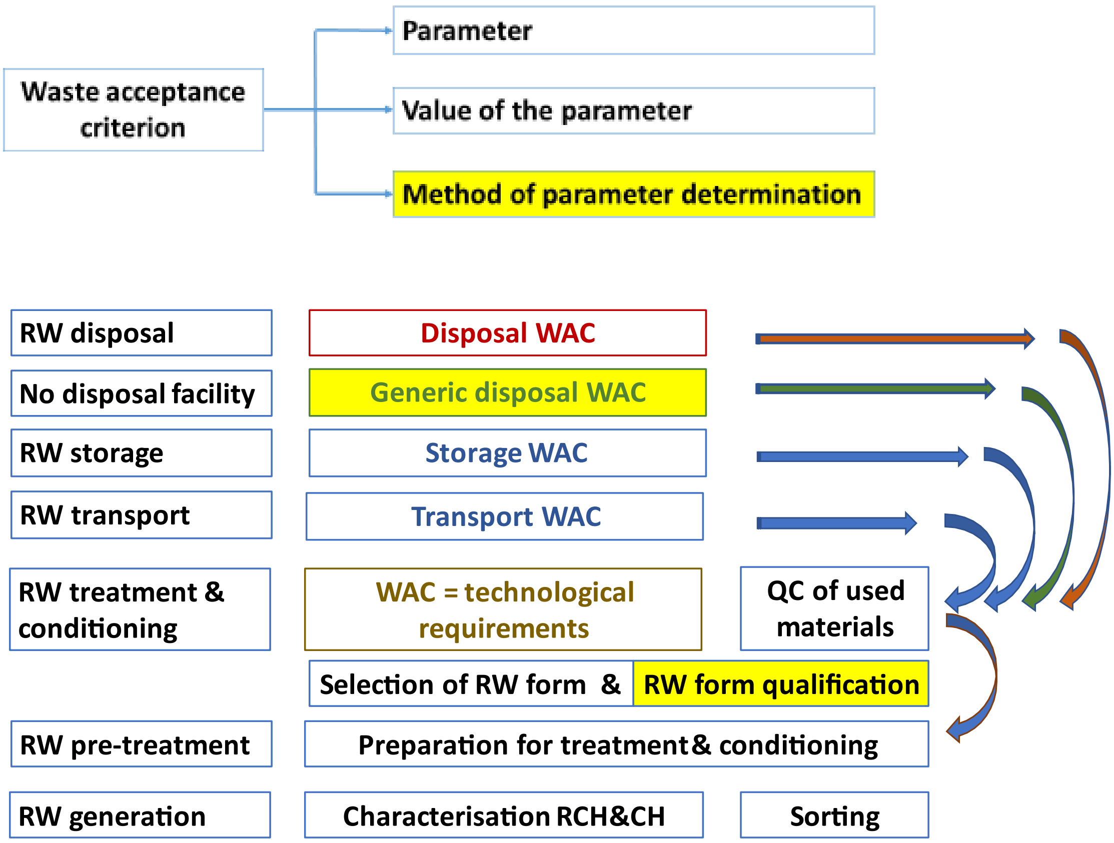

Figure 1: Indication of T2.3 areas of interest in a waste acceptance system.

Table 1 indicates which countries were investigated by Task 2.3 partners and the availability of disposal facilities in these countries. They were selected with consideration of the status of their waste management programme and availability of information.

The national analyses deal with topics listed below:

a) The status of RWM (regarding only very low, low, and intermediate level waste, i.e., without high level waste) and the level of formal and technical infrastructure,

b) The approach to the waste acceptance system (including a predisposal phase),

c) Existence of requirements (limits and conditions) for acceptance in particular RWM phases,

d) The list of parameters and requirements included in waste acceptance criteria,

e) The list of methods used to check WAC,

f) The description of the waste form qualification process (bringing the evidence that waste packages can be accepted to a disposal facility).

Table 1: The list of countries included in the investigation.

Country	Repository in operation	Repository in preparation	No repository	Comment
Australia		+		
Austria			+	
Belgium		+		
Bulgaria	+*	+		* RADON facility
Croatia			+	
Czech Republic	+			
Finland	+			
France	+	+		
Germany	+**	+		** Closed facilities
Greece			+	
Hungary	+	+		
Iran	+	+		
Italy		+		
Japan	+			
Lithuania	+	+		
Moldova	+*			* RADON facility
Norway	+	+		
The Netherlands			+	WAC for long term storage
Portugal			+	
Romania	+	+		
Slovakia	+			
Slovenia	+*	+		* Disposal of U tailings
South Africa	+			
Spain	+			
Sweden	+	+		
Switzerland		+		
UK	+	+ ***		*** Ongoing development of a GDF
Ukraine	+	+		
US/WIPP	+			

It should be noted that detailed information regarding WASs was not identified for all countries. Table 2 indicates to which extent the goals of this analysis were achieved.

Table 2: Relevancy of provided information.

Country	Infrastructure		Waste management system		WAC parameters	WAC measuring techniques	Waste form qualification	Generic WAC
	Formal	Technical	Centralised	Decentralised				
Australia	+	+	+		+			+
Austria	+	+	+		+			
Belgium	+	+	+		+	+	+	+
Bulgaria	+	+	+		+			+
Croatia	+	+	+		+			+
Czech Republic	+	+	+		+		+	
Finland	+	+	*)	+	+	+		
France	+	+	+		+			
Germany	+	+	+		+	+	+	
Greece	+	+	+		+			
Hungary	+	+	+		+	+	+	
Iran	+	+	+		+			+
Italy	+	+	+		+		+	+
Japan	+	+	*)	+	+		+	
Lithuania	+	+	+		+	+		+
Moldova	+	+	+		+			+
Netherlands	+	+	+		+			**)
Norway	+	+	+					
Portugal	+	+	+					
Romania	+	+	+		+	+		+
Slovakia	+	+	+		+		+	
Slovenia	+	+	+		+			
South Africa	+	+	+		+			
Spain	+	+	+		+			
Sweden	+	+	+		+		+	
Switzerland	+	+	+		+		+	+
UK	+	+	+		+	+		***)
Ukraine	+	+	+		+	+		
US/WIPP	+	+			+	+		

*) - Centralised management of HLW/SNF
**) - WAC defined for long term storage
***) - Generic WAC formulated for Higher Activity Waste (HAW) disposal

2.3 RWM status

Radioactive waste management in all investigated countries is well established with the existence of both formal and centralised technical infrastructures ensuring the waste is under state control which is achieved by performing RWM services by a waste management organisation. Non-nuclear countries having just institutional waste tend to ensure waste collection, conditioning, and storage in a single institution. Two exceptions are Finland and Japan where a centralised system is established only for HLW/SNF management, but disposal facilities which provide routes and end points for generated low and intermediate level waste are available.

Even if there are differences in waste classification systems, segregation of waste streams which can be disposed of in near surface and those requiring geological disposal is well distinguished.

Responsibilities for RW collection, processing, storage, and disposal are clearly allocated as well as independent supervision by regulatory bodies. Waste processing and storage facilities are in place even in countries without repositories as there is a clear preference to condition wastes and store them until adequate disposal capacities are available. For that purpose, most countries have defined requirements on the properties of waste packages, at least in the form of preliminary or generic WAC.

Information about the application of WAC in the predisposal stages is rather limited, even if requirements apparently exist, they are not described in national analyses. Sometimes, they are considered as limits and conditions arising from disposal WAC, e.g., presence of some chemicals, hazardous materials, chelating agents, pyrophoric material, etc. The elaboration of links and dependencies among disposal criteria regarding these features and initial characterisation of generated waste streams is worthy of further investigation as they may affect the selection of treatment technologies for some waste streams.

Radiation safety related criteria are incorporated in all programmes in terms of limiting surface contamination and dose rates to ensure safety while handling and transporting waste packages. Specific activity limits of radionuclides are established based on the safety analyses of disposal facilities, and where it is relevant, activities of fissile and other selected radionuclides (Ra^{226}) are controlled as well. These limits are defined also in some preliminary WAC, apparently, based on international experience.

Rather complex information was collected regarding the selection of waste acceptance requirements and parameters and a simplified overview is shown in Table 3. The table contains generalised items, some of the parameters are elaborated in more detail in the national analyses.

The frequency of the use of various parameters in particular countries is visible from the table. Empty boxes do not necessarily indicate missing parameters, they may denote just insufficient information about the actual status of the WAS.

Requirements on waste containers are defined systematically, starting with their shape dimensions, volume, weight, and material, mechanical characteristics, stacking durability, and resistance to corrosion, irradiation, and fire. Examples exist where the containers do not have any safety function and function just as a handling units (typically for VLLW, but also for LLW).

Radioactive waste repositories are generally not intended for accepting hazardous, biodegradable, and toxic materials. For safety reasons the presence of some chemicals (aggressive, chelating) is not allowed or is strongly limited.

Gas generation, heat production, free liquids, fire resistance of solidified waste and their packages are other parameters taken into account.

Administrative requirements include unique identification of every waste unit (package, solid items), datasheets containing information about radionuclides present in the waste, waste forms and process of their conditioning, properties of the waste package, declaration of compliance with WAC, and databases where all information about waste is kept and maintained, including waste position in the storage or disposal facility.

Specific criteria are formulated in some programmes for the management of disused sealed radioactive sources (DSRS), namely for their storage. Typically, requirements address type and quality of containers (dimension, mass, shielding capacity, tightness), radiation safety parameters (radionuclides present in the source and their activity, contamination, dose rate), and identification measures.

Table 3: The list of parameters and requirements included in waste acceptance criteria.

Country	Only solid/solidified RW	Mechanical stability		Homogeneity	Dose-rate	Surface contamination	Alpha specific activity	Beta/gamma spec. activity	Fissile element mass	Radiation & thermal & chemical stability	Package (damage, weight, type)	Physically hazardous materials: flammable, explosive, aggressive	Putrescence, fermenting, infectious	Void space	Built-up pressure in RW	Gas generation	Heat generation	Organic content	Chemo-toxic waste	RW swelling	Free liquids	Reactive (electropositive) metals	Chelating/complexing agent	Leaching	Passport/labelling
Australia*	+	+			+	+	+	+	+		+	+									+	+	+		+
Austria	+				+	0					+	0	0		0										
Belgium*	+	+			+	+	+	+	+		+	+	0			+	+	+		+	0	+	+		+
Bulgaria		+			+	+	+	+			+	0											0	+	+
Croatia*		+		+	+	+	+	+		+		+		+				+			+		+	+	+
Czech Republic	+				+	+	+	+	+	+	+	+	+			+			+		+		+	+	+
Finland**	+											+			+				+			+			+
France		+		+	+	+	+	+	+		+	+	0									+			+
Germany*	+				+	+	+	+	+		+		0		+			+	+		+	+			+
Greece					+	+	+	+	+	+	+	+	+			+	+	+	+		+		+		+
Hungary		+		+	+	+	+	+	+		+	+				+			+		0	+	+	+	+
Iran*	+	+			+	+	+	+	+	+	+	+	+	+		+	+		+		+	+	+	+	+
Italy*	+	+			+		+	+		+	+	0	0	+				+			+	0	+	+	+
Japan	+	+		+	+	+	+	+	+		+	0		+								+			
Lithuania		+			+	+	+	+	+			+		+		+		+	+				+	+	+
Moldova [#]	+	+		+	+		+	+	+	+	+	0	0								+	+	+	+	+

Country	Only solid/solidified RW	Mechanical stability		Homogeneity	Dose-rate	Surface contamination	Alpha specific activity	Beta/gamma spec.	Fissile element mass	Radiation & thermal stability	Package (damage, weight, type)	Physically hazardous materials: flammable,	Putrescence, fermenting, infectious	Void space	Built-up pressure in RW	Gas generation	Heat generation	Organic content	Chemo-toxic waste	RW swelling	Free liquids	Reactive	Chelating/complexing	Leaching	Passport/labelling
Netherlands ##	+	+			+	+	+	+	+	+	+	+	+	+		+		+	+		+		+		+
Norway					+																				
Portugal					+	+		+			+														+
Romania ###	+	+		+	+	+	+	+	0	+	+	0				+					+				+
Romania *	+	+			+	+	+	+			+	0	0	+		+	+		+			+	+		
Slovakia					+		+	+	+		+	+				+								+	+
Slovenia*	+	+		+	+	+		+		+	+	+	+	+		+		+	+		+		+	+	+
South Africa	+	+		+	+	+	+	+	+		+	0	0	0	0				0		0	0	0		+
Spain	+				+	+	+	+			+	0	0	+	0	0		+	0		0	0	0		+
Sweden	+	+		+	+	+	+	+	+	+	+	0		+		+		+	+	+	0	+	0		+
Switzerland		+			+	+	+	+		+	+	0		+		+	+			+	0		+	+	+
UK - LLW					+	+	+	+	+		+	+	0	+	0	+	+	+	+		+	+	+	+	+
UK - HAW *		+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+		+
Ukraine		+		+	+	+	+	+	+	+	+	+	+	+		+	+	+	+		+		+	+	+
US/WIPP				+	+	+	+	+	+			0		+	0		+		+		+				+

*Generic/preliminary criteria, will be updated with the commissioning of a disposal facility
**WAC valid for FORTUM disposal facility
#Moldova has defined WAC, Generic WAC, WAC for DSRS packages
##WAC for long term storage
###WAC for institutional waste repository Baita Bihor
0 - Banned item

3 LIST OF METHODS USED TO CHECK WAC

The collected national analyses provide a good overview of the waste acceptance systems in the investigated countries, but inputs regarding methods and procedures for measuring WAC parameters and demonstration of their compliance with requirements are rather narrow. Some information might be found in references which are a part of national analyses. Nevertheless, for the successful completion of the planned goals it will be necessary to collect and research additional literature and publications and utilize expert capacities and experience gained by the responsible manager of the subtask. It should be noted that radioactivity analytics and radioactive waste characterization is a part of ISOTOPTECH's profile (including gamma assay of radioactive waste packages, off-site radiochemical separation and measurement of DTM isotopes, determination of scaling factors for DTM isotopes, special applications, e.g., gas/heat generation monitoring of various rad. waste types, etc.). Furthermore, the institute experts follow the development in methods and equipment, and keep knowledge about the needed expertise, preparedness, and laboratory background for these methods.

To support this effort, the subtask manager formulated an additional questionnaire to be sent to PREDIS partner countries/representatives regarding specification of radioactive isotopes and radioactivity properties of the waste that they need to measure for their WAC, and methods and instruments they currently use to measure these isotopes and properties.

A short description of methods from the national analyses used for WAC demonstration in selected countries is presented in the following sections.

3.1 Belgium

Chemical composition *(estimations or quantifications)*

The waste typology is derived from the general knowledge of the waste, supported (if needed) by physical inspections. Identification of specific materials or chemical species and determination of their masses is done based on the general knowledge of the waste, supported (if needed) by physical inspections and laboratory analysis.

Of specific interest are water-soluble phosphates & chlorides, fluorine, electropositive metals, cellulose content and pH.

Other properties (e.g., dimensions, type of polymers) are linked to the treatment & conditioning process. For example, the alkali-silica reaction (ASR) must be excluded for any waste containing concrete rubble. The ASR must also be excluded for any material used in a cement-based immobilization matrix for conditioned waste (test method: ASTM C 1260 or 1293). Similarly, delayed ettringite formation (DEF) needs to be excluded in concrete rubble or in the immobilization matrix. Sensitivity to DEF in concrete rubble can be detected using petrography.

Radiological properties

The activities of radionuclides are derived from dose rate measurements and the application of a vector which is specific to the waste stream.

The characterisation process is based on the following techniques:

- gamma-spectrometry (for key nuclides determination) combined with an approved nuclide vector (NV) based on models, calculations and possibly destructive measurements,
- dose rate (measured on non-conditioned waste packages) conversion with approved NVs determined using software such as MicroShield (calculation of NV through specific conversion factors – mSv/h to MBq),
- destructive analysis on samples and approved NV,
- neutron measurements on conditioned waste,

- mass spectrometry, gamma spectrometry and alpha spectrometry on samples of non-conditioned waste.

Activities for a standard list of 63 radionuclides and dose rates need to be reported. Techniques used & uncertainties: see questionnaire CHANCE-project (report D2.2, contract number 755371).

Non-destructive techniques: gamma spectrometry (Q^2, 3AX, ISOCS) using gamma-emitters.

Destructive techniques: Sampling, chemical separation and radiometric determination (using alpha-emitters, Ni-59, Ni-60, H-3, C-14).

3.2 Germany

Chemical and radiochemical characterisation is required to determine elemental composition and radionuclide vectors. Methods have to be described and need a permit by the relevant authority or BGE (waste management organisation).

Waste characterization usually consists of the following steps:

- source/origin, material pre-sorting (mainly material stream separation) and radiological pre-sorting (gamma activity / dose rate survey),
- conditioning input characterization: sampling for radio-chemical analysis (RCA), QA docs and ID/origin checks, temperature-range stability (thermogravimetry), outgassing control, temperature survey, dose rate at the surface and at 1m distance,
- measurement portfolio: dose rate/gamma spectroscopy (sample or in situ), calorimetry
- determination of heat, density, volume, mass, homogeneity, centre-of-mass, transport/handling assurance,
- swabbing and contamination tests for non-sticking volatile contamination: α-, β-, γ-activity,
- sampling-statistics, random sampling for RCA, elemental and phase component analysis: methods applied are LSC (α- and β-activity), γ-spectrometry, AAS, ICP-MS, ICP-OES, Total Organic Carbon (TOC), NNA, QA-process control parameters, uncertainty assessment, pH, pE / anti-corrosion/leaking / leaching assurance.

The methods used are the following:

- radio-chemical analysis (RCA),
- elemental and phase component analysis: methods applied are LSC (α- and β-activity), γ-spectrometry, AAS, ICP-MS, ICP-OES,
- Total Organic Carbon (TOC),
- temperature-range stability (thermogravimetry),
- outgassing control (gas-chromatography),
- dose rate at the surface and at 1m distance, calorimetry,
- determination of density, volume, mass, homogeneity, centre-of-mass,
- swabbing and contamination tests for non-sticking volatile contamination: α-, β-, γ-activity.

3.3 Finland

The regulator (STUK) advises that the methods used in the activity assays depend on the properties and method of packaging of the waste, as well as the radionuclide composition of the waste, and the uniformity of the activity distribution. The general guidelines below are provided for waste activity determination.

- Dose rate and activity margin measurements are suitable as confirmatory methods. They are suitable as the main method when the radionuclide composition at the measurement site is known with sufficient accuracy.
- Gamma spectrometric monitoring is particularly suitable for sites where the activity distribution is uneven, and the radionuclide composition varies (e.g., maintenance waste packages). The activity concentrations of radionuclides emitting little, or no gamma radiation must then be

estimated by indirect methods, e.g., by relating the activity of a suitable gamma emitter using safety margins.

- Sampling and analysis of samples are suitable for wastes in which the radioactive substances are sufficiently evenly distributed or for which the activity distributions are known in advance. The method can also be used to determine proportionality factors that indicate the proportion of substances that emit little or no gamma radiation.
- The design of measurement procedures shall take into account the effect of measurement geometry, self-absorption, measurement frequency and other relevant factors on the representativeness of the measurements. The measuring equipment must be calibrated with sufficient frequency using radiation sources representative of the energy range to be measured.
- If the origin and radionuclide composition of the waste are more or less constant, the activity can be determined from a statistically representative number of waste packages. In this case, the radionuclide-specific activity of other waste packages can be calculated on the basis of the measured dose rates and the measured radionuclide compositions.
- Contamination of waste packaging shall be prevented as a matter of priority by keeping handling and storage facilities clean. If waste packages are suspected of being significantly contaminated, their activity margin shall be checked by measuring a statistically representative number of packages before they are placed in storage.

3.4 Hungary

The verification of the content of materials which are intended to be disposed of is controlled by the waste producer and by the repository operator (PURAM). The former checks in detail every 100th waste bag/package, carries out gas sampling and gas analysis, and analyses the fissile material content and activity range, while the later does a random check during waste collection at the NPP site by opening some bags and checks the analyses performed by the waste producer regarding activity measurements.

Table 4 summarises measuring methods regarding physical and chemical properties of waste, Table 5 provides information about methods used for the determination of isotope specific acceptance criteria, and Table 6 describe determination of radioactive characteristics of waste/waste packages.

Table 4: Requirements in connection with the physical and chemical features of the waste.

Parameter	Acceptance criteria	Verification by waste producer	Control by waste producer	Control by PURAM
Dust content	❖ Maximum 1 % of particles smaller than 10 µm and ❖ Maximum 15 % of particles smaller than 100 µm	Internal regulations relating to waste collection	Detailed check of every 100th waste bag	Random check during waste collection at NPP site, and opening of some bags
Structural stability	Void volume max. 10%	Fulfilment of the waste collection rules and compressing by the 500 kN press	Detailed check of every 100th waste bag	Random check during waste collection at NPP site, and opening of some bags
	Compressive strength is greater than 10–30 N/mm^2	Not applicable for this waste form		

Parameter	Acceptance criteria	Verification by waste producer	Control by waste producer	Control by PURAM
Corrosive materials	Less than 1 weight%	Internal regulations relating to waste collection. Technological prescriptions excluding corrosive wastes	Detailed check of every 100th waste bag	Random check during waste collection at NPP site, and opening of some bags
Effects of heat and radiation	If the heat generation is higher than 20 W/m^3, the effects must be analysed	With analysing (the max. activity range)	–	Revising the analysis
Gas generation Hydrogen and other explosive gases organic and elementary gases	Pressure higher than 0.5 bar cannot occur	Internal regulations relating to waste collection	Gas sampling, gas analysis	Revising the analysis
Free liquid	Max. 1 volume%	Technological prescriptions avoiding free liquids	Detailed control of every 100th waste bag	Check of the fulfilment of the technological prescriptions'
Chelating and complexion agents	Max. 0.5% of the waste being conditioned	Not applicable for this waste form		
Leaching rate	Max. $5*10^{-5}$ $g/cm^2 s$ (evaluated based on ASTM C1308-95 standard)	Not applicable for this waste form		
Homogeneity	The waste types cannot be mixed This can be accomplished by sorting and separately packaging the single waste types	Internal regulations relating to waste collection	Detailed control of every 100th waste bag	Random check during waste collection at NPP site, and opening of some bags

Table 5: Methods for the determination of isotope specific acceptance criteria.

Isotope	Maximum activity-concentration [Bq/drum]	Verification by waste producer	Control by waste producer	Control by PURAM
^{3}H	7,32E+13	SF method	Calibration Regular review of the Scaling Factors	Control of the QA/QC measures of Paks NPP Own measurement
^{14}C	5,58E+12	SF method		
^{36}Cl	5,20E+09	SF method		
^{54}Mn	1,34E+11	Direct measurement		
^{55}Fe	1,01E+12	SF method		
^{58}Co	2,80E+12	Direct measurement		
^{59}Ni	5,70E+12	SF method		
^{60}Co	1,99E+10	direct measurement		
^{63}Ni	2,40E+12	SF method		
^{90}Sr	1,72E+10	SF method		
^{94}Nb	2,34E+10	Direct measurement		
^{99}Tc	3,24E+11	SF method		
^{110m}Ag	4,46E+11	Direct measurement		
^{124}Sb	2,02E+11	Direct measurement		
^{129}I	2,62E+09	SF method		
^{134}Cs	1,03E+10	Direct measurement		
^{137}Cs	1,36E+10	Direct measurement		
^{141}Ce	2,80E+13	Direct measurement		
^{144}Ce	2,80E+13	Direct measurement		
^{234}U	1,02E+10	SF method		
^{235}U	4,36E+10	SF method		
^{238}U	2,94E+10	SF method		
^{238}Pu	1,28E+10	SF method		
^{239}Pu	1,14E+10	SF method		
^{240}Pu	2,80E+11	SF method		
^{241}Am	1,42E+10	Direct measurement		
^{242}Cm	2,22E+11	SF method		
^{243}Am	1,41E+10	SF method		
^{244}Cm	2,30E+10	SF method		

SF: scaling factor

Table 6: Determination of radioactive characteristics of waste/waste packages.

Parameter	Acceptance criteria	Verification by waste producer	Control by waste producer	Control by PURAM
Contact dose rate	Less than 10 mSv/h on the drum's surface	Direct measurement	Instrument calibration	Repeated measurement before transportation
Surface contamination	❖ beta-gamma radiators max. 4 Bq/cm^2, ❖ alpha contaminators maximum 0.4 Bq/cm^2	Smear sampling and direct measurement	Instrument calibration	Repeated measurement before transportation

3.5 Italy

Tests administered to the container are specified in Technical Standard UNI 11196; tests administered to the waste form and waste package are specified in Technical Standard UNI 11193. Requirements are specified in the Table 7.

Table 7: Qualification tests and requirements for container and waste package.

Test	**Container**	**Package**	**Requirements**
High temperature resistance		x	No cracks after 30 min at 1073°K
Free liquid absence		x	< 1 % of internal volume
Degradation resistance	x		After 90 d immersion of container material in a degradation solution the level of degradation shall be evaluated to ensure container safe performance until waste disposal
Stacking resistance		x	According to the IAEA Safety Standard Series No. TS-R-1
Drop resistance		x	According to the IAEA Safety Standard Series No. TS-R-1
Penetration resistance		x	According to the IAEA Safety Standard Series No. TS-R-1
Tightness	x		Closed container pressurised to at least 0.05 bar must maintain at least 90 % of the initial pressure after 60 min

3.6 Lithuania

Methods used to determine WAC parameters are as follows:

- Dose rate measurement at 0.1 m distance from the surface is used for sorting of solid RW.
- Chemical analysis of representative samples taken in the waste pre-treatment or treatment process is done at laboratory for determination of chemical composition of the waste form.
- Weighting on the platform of a container with the waste or waste package is applied for measurement of mass of RW.

- Determination of radionuclide content in the container or waste package is done by measurement of gamma rays with spectrometric equipment for strong gamma emitters (key nuclides, Co-60 and Cs-137) in measuring chamber and by multiplying of results of gamma measurement with scaling factors for difficult-to-measure radionuclides (alpha, beta and weak gamma emitters).
- Determination of scaling factors for difficult-to-measure radionuclides is done by measurement of the ratio of specific activity of difficult-to-measure radionuclides with key nuclides in representative samples or by modelling, if reasonable.
- Destructive analysis of samples for measurement of specific activity difficult-to-measure radionuclides is done by incineration and radiochemical preparation.
- Alpha, beta, gamma and inductively coupled plasma mass spectrometry is applied for measurement of specific activity of difficult-to-measure radionuclides after destructive analysis of samples.
- Modelling of the specific activity of difficult-to-measure radionuclides is done by simulation of nuclear fuel depletion in the reactor and activation of reactor materials for determination of the ratio of specific activity of different isotopes of the same chemical element or for determination of the ratio of specific activity of isotopes of chemically similar elements.
- Determination of non-uniformity distribution of the gamma-emitting radionuclides in the waste container and waste package is done in a measuring chamber with one semiconductor gamma-spectrometer and three pairs of gamma-radiation scintillation spectrometers (in total 6 pieces), placed on top on the mobile construction and along the sides of the controlled object (container or package).

3.7 Romania

The following methods for waste characterisation are implemented to determine waste compliance with acceptance criteria. The WAC have been developed for Baita Bihor facility which accepts institutional waste. A disposal facility for NPP generated waste is under development and, thus, procedures regarding the determination of relevant WAC parameters are being formulated.

For raw waste: gamma spectrometry, alpha spectrometry, LSC, dose rate measurements.

For conditioned RW prepared for disposal: the activity of gamma emitters is measured by gamma spectrometry carried out directly on the conditioned waste, while the activities of alpha and beta emitters are based on the characterisation of the raw waste and on a certified analysis document received from the waste generators (usually the waste characterization is performed by the specialised and licensed laboratory from IFIN-HH-Department of Radioactive Waste Management).

Ensuring waste compliance with WAC is the responsibility of the producer of the raw RW or the waste packages.

3.8 Switzerland

For cemented waste products, the following data are required:

- Compressive strength: After hardening, waste product samples are exposed to mechanical loading. The samples must withstand a minimum load of 10 MPa.
- Leaching: Leach rates for the key test nuclides Co-60 and Cs-137 determined over a period of 150 days should be below 5 E-6 m/day. Tests are performed in demineralised and saturated gypsum water.
- Water (and sulphate) resistance: Investigation of the stability of waste products upon water infiltration. Only when the compressive strength of the sample exposed to an aqueous medium is (still) above 10 MPa and the volume increase is less than 5% is the waste product considered water- (and sulphate-) resistant.

For bituminised and polystyrene waste products, the following data are required:

- Flash, burning, ignition points: Samples (usually inactive simulates) are heated until they begin to flash and burn and escaping gases ignite. This test provides information on the resistance of the waste product to thermal loading.
- Softening point: This test is used to determine the point at which the waste matrix begins to flow, and the potential separation of bitumen and waste occurs.
- Viscosity (only bituminised waste products), e.g., determined by needle penetration: Determines the hardness of the product via the penetration depth of the needle to which a normalised force is applied.
- Leaching: As for cemented waste products
- Water (and sulphate) resistance: As for cemented waste products without the requirement of compressive strength above 10 MPa.

A radiological waste characterisation programme is performed in parallel with conditioning. Representative raw waste samples, e.g., from the NPP cleaning circuits, are taken and analysed. The activity measurements include the following “reference nuclides”:

- γ emitters such as Co-60, Cs-137/Ba-137m, Mn-54, Cs-134, Ce-144/Pr-144
- β and X-ray emitters such as H-3, C-14, Cl-36, Fe-55, Ni-63, Sr-90, Tc-99, I-129, Pu-241
- α emitters such as U-235, U-238, Pu-238, Pu-239/240, Am-241, Cm-244

Based on these measurements, the activities of these and other nuclides that are difficult to measure are related to the activity of the “key nuclides” Co-60 and Cs-137/Ba-137m. Using these “correlation factors”, the total nuclide inventory of the waste packages can be determined based, e.g., on gamma scans for Co-60 activity of waste packages. Wastes from the reactor pressure vessels which have been activated by a significant neutron flux are characterised by activation calculations, which are validated and verified by measurements.

3.9 UK

The following techniques are required to check compliance with WAC for the Low-Level Waste Repository (LLWR):

- Sampling and sample analysis.
- Derivation of a waste fingerprint.
- Categorisation of the waste.
- Radioactivity measurements, including determining the amount of certain radionuclides.

The characterisation techniques to be used are not prescribed. However, methods used to verify compliance with WAC include both non-destructive methods, such as physical inspection, radiometric measurements, or gamma spectrometry, and destructive methods, such as radiochemical analysis, which are used to check waste package compliance with WAC either for storage or for disposal.

Dose rate measurement is the most widely used radiometric method for checking compliance of waste packages. However, other methods such as specific nuclide vector / scaling factors, the dose to Becquerel methodology complement dose rate measurements to derive radionuclide activities. It is noted that these methods require good knowledge of the origin and/or history of the waste, which can be problematic for legacy wastes.

Measurement of the masses for specific materials or chemical / toxic species in the waste, characterisation of challenging wastes, such as legacy wastes or heterogeneous wastes, and measurement of difficult to measure radionuclides are indicated as the biggest difficulties for checking waste package compliance with WAC.

3.10 Ukraine

At NPP's, the spectrometer SEG-001m "AKP-S" is used for the determination of activity of radionuclides of solid non-sorted radioactive wastes in primary packages at places of radioactive wastes generation: all radionuclides exceeding 1-2 % of the total activity are measured.

In particular, the following waste streams are subjected to activity control:

- solid non-sorted radioactive wastes in primary packages at places of formation of radioactive wastes,
- solid non-sorted radioactive wastes placed in metal packages of various forms and sizes at places of its collection, and
- radioactive wastes of 1 and 2 groups placed in containers before sending to storage.

3.11 United States – Waste Isolation Pilot Plant (WIPP)

WAC compliance is demonstrated by the standard test methods defined by the American Society for Testing and Materials (ASTM Series) and American National Standards Institute (ANSI Series). Their use is furthermore elaborated in implementation documents developed by the DoE, Carlsbad Field Office. For more details see the references to Annex A of the transuranic (TRU) WAC for WIPP.

All TRU waste generators perform confirmatory testing, as described in their Certification Plans. The standard confirmatory testing methods for characterizing RH TRU waste include:

- visual examination of 100% of waste requiring packaging or repackaging,
- visual examination or radiography of 10% of waste already packaged in payload containers,
- dose-to-curie conversion,
- destructive assay, and
- non-destructive assay.

The methods of compliance demonstration at WIPP include namely the following:

- visual examination of waste packages,
- visual inspection of waste packages,
- radiography,
- records and database information,
- administrative and procurement control,
- sampling programme for destructive analyses, and
- measurement (dose rate, surface contamination).

Characterisation methods and their objectives are presented in the Table 8.

Table 8: Characterisation methods and objectives.

Characterisation method	Characterisation objectives
Acceptable knowledge	TRU waste determination, total activity, activity per canister, defence determination, physical form, residual liquid
Dose-to-curie	TRU waste determination, total activity, activity per canister
Visual examination	Physical form, residual liquid
Radiography	Physical form, residual liquid
Radioassay	TRU waste determination, total activity, activity per canister
Surface dose rate	Surface dose rate
Count containers	Metal weight

4 DESCRIPTION OF WASTE FORM QUALIFICATION PROCESS

The 'qualification' determines the '*a priori'* conformity of the waste with applicable waste acceptance criteria, however, its understanding differs from country to country, probably because interpretations of what is encompassed by 'waste form qualification' are somewhat variable and subjective. Basically, there are two aspects of this matter:

a) ***Qualification process*** bringing evidence that a considered waste form, including its conditioning technology and package, conforms to the design and relevant limits and conditions of a disposal facility where the waste shall be disposed of, and that its long-term performance in the disposal system will not jeopardise the required level of safety as defined in the facility safety case.

b) ***Qualification procedure*** demonstrating that waste has been processed and maintained so that it complies with defined WAC.

While the objective of our project is primarily to advise on the former interpretation, the national analyses contain mostly descriptions of procedures dealing with the later.

The link between these two approaches is the selection and definition of certain WAC based on experiments and tests performed in the qualification process. They are aimed at understanding the long-term performance of a waste form and the definition of limit values of investigated parameters. This also means that without a final disposal solution (known design and site) it is hardly possible to conclusively confirm the selection of a treatment/conditioning technology for a particular waste stream. On the other hand, WAC defined as a result of the qualification process can be drivers for adapting design and siting of the repository. In any case, proper understanding of characteristics of the waste form and its performance might be later employed in the final confirmation of adequate WAC for accepting conditioned waste to repository once it has been developed.

The qualification procedure confirms that the treatment and conditioning processes, the radiological characterization methodology and the primary waste package meet all requirements that must be addressed in order to generate a waste form that complies with the applicable acceptance criteria. Qualification is a prerequisite for the radioactive waste to be accepted and collected by repository. It contributes to guaranteeing that the waste will be managed in accordance with the required safety rules and conditions.

Not all national analyses contain information about waste form qualification. In spite of this lack, generalization of the responses regarding this issue seems to be manageable with the support of other references and personal experience of key experts.

Short descriptions of approaches to waste form qualification in selected countries is in the following sections.

4.1 Belgium

The waste acceptance system applied by ONDRAF/NIRAS consists of three parts: the acceptance criteria, a qualification process, and an acceptance process. Figure 2 shows that every stage of the acceptance of radioactive waste is accompanied by WAC.

WAC

WAC are contained in formal documents (referred to as 'ACRIAs') which give the minimum requirements to the applicable waste category for waste to be accepted and are supported by Technical Notes and Procedures which give details of specific technical aspects and acceptance arrangements, respectively.

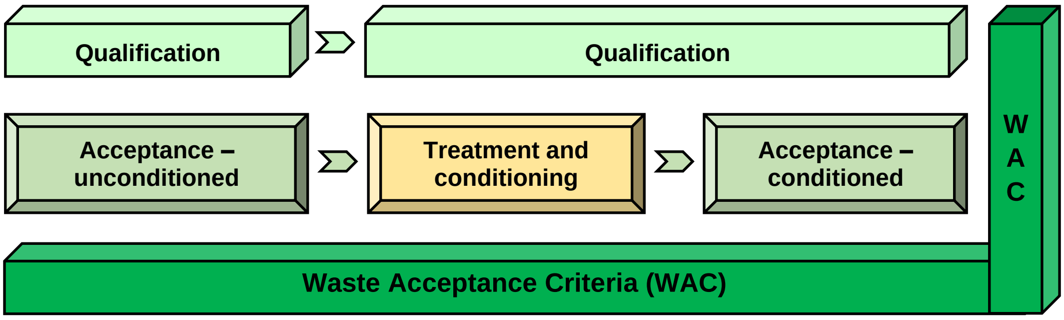

Figure 2. Principles of the ONDRAF/NIRAS radioactive waste management system.

Qualification or agreement

Satisfactory qualification is a necessary condition of waste acceptance, consisting of approval of the Technical Qualification Dossier submitted by the producer for their unconditioned and conditioned radioactive wastes demonstrating suitability of methods and equipment, together with on-site verification inspections by ONDRAF/NIRAS and verification of the producer's quality procedures.

The qualification process confirms that the treatment and conditioning processes, the radiological characterization methodology and the primary waste package meet all requirements that have to be fulfilled in order to produce radioactive waste that complies with the applicable acceptance criteria. The acceptance criteria serve as a guiding principle for the qualification operation. The purpose of the qualification is to make sure that a process, method or facility is able to produce and/or characterize radioactive waste that meets the applicable acceptance criteria. Qualification is a prerequisite for the radioactive waste to be accepted and collected by ONDRAF/NIRAS. It contributes to guaranteeing that the waste will be managed in accordance with the required safety rules and conditions.

The waste processing, conditioning, and storage facilities

Qualification is declared at the end of three stages:

- The approval, by ONDRAF/NIRAS, of a technical qualification file written by the waste generator, which describes the functioning of the process and the facility and their ability to deliver end products that meet the applicable acceptance criteria,
- The satisfactory verification of conformity between the information documented in the technical qualification file and its implementation in the facility to be approved. This verification (technical audit) is performed at the facilities concerned,
- The satisfactory examination of the documentation compiled by the waste generator to demonstrate the conformity of the waste produced and verified in the facilities to be approved.

The methodology for characterizing the waste and ensuring its compliance with the acceptance criteria

The qualification of a radiological characterization methodology (and possibly, of a measuring facility and method), in addition to the methods used to ensure that the waste meets the acceptance criteria, is also based on specific qualification files.

The primary package of the conditioned waste

Qualification of the primary package for conditioned radioactive waste consists of the inspection and verification of the package's compliance with the specific requirements established by ONDRAF/NIRAS.

Qualification determines the 'a priori' conformity of the waste with applicable waste acceptance criteria.

4.2 Czech Republic

The Czech Republic has limited legislative support of the qualification process of RAW in the case that there is no repository available. The waste producer is allowed to produce RAW in the amount and in the form specified in the limits and conditions of operation of the facility under SÚJB (the Nuclear Regulator) operational permission. Limits and conditions of operation usually respect the possibility of future RAW disposal in one of the existing repositories, but in most cases this possibility is supported economically and technically, but not explicitly, by the waste producer – repository operator (SÚRAO) relationship.

The final waste form qualification process is assured by meeting the WAC of the respective repository and must be supported by a safety assessment. The repository operator is responsible for the safety assessment implementation using all known data of a host structure and a final waste form, with respect to radiological constraints and hygieneel regulations. Parameters used as inputs in safety evaluation have to be checked for all waste forms specified for disposal. SÚRAO as a repository operator submits to the SÚJB a proposal of updated operational limits and conditions including WAC. The WAC document is valid after SÚJB approval.

In the Czech Republic (the disposal facilities are in operation), the procedure described in Figure 3 is applied to qualify a waste for disposal.

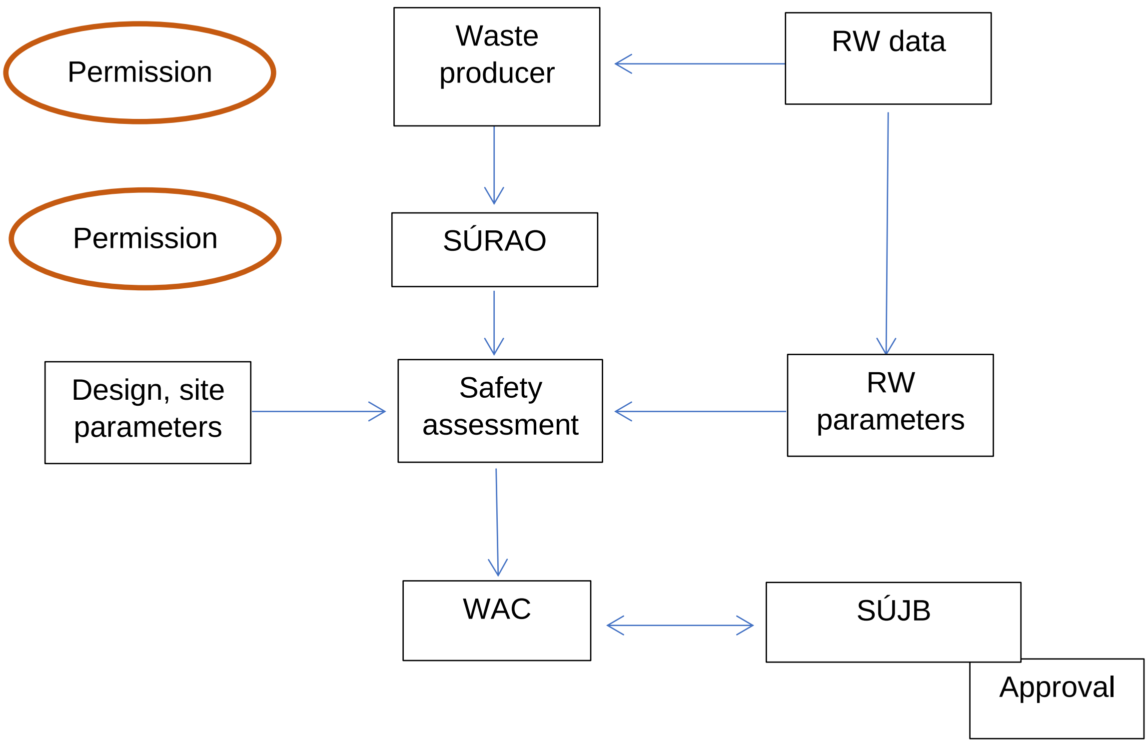

Figure 1:The scheme of waste form qualification process in the Czech Republic.

4.3 Germany

If treatment of raw wastes must be performed, waste producers are obliged to declare the radionuclide inventory and provide the plan for the treatment, conditioning and packing of the wastes. BGE (a waste management company) has the controlling function over every step of the waste management process. Producers are providing the plan for waste retrieval, treatment, conditioning, and packaging. If the plan is approved by the BGE, the BGE subcontracts the supervision over the waste processing process to an independent expert company, like Technischer Überwachungsverein (TÜV) or Produktkontrollstelle (PKS). After the packaging of wastes is completed, TÜV (or PKS) provides their report (documentation of the process) to the BGE, where a decision about the disposability of the waste is made. A decision has to be issued for every single waste package, and documentation of the waste package is stored at the BGE in perpetuity.

A difficulty might be concerned with heterogeneous wastes, where characterisation of an aliquot sample cannot often be up scaled to the total amount of a waste batch.

Wastes to be retrieved from Asse mine are not sufficiently characterized, as there is no identification on the buried drums. Currently, there is no specific procedure implemented to characterize this waste in a non-destructive way.

4.4 Hungary

The WAC objective is to provide evidence that the waste packages can be accepted to a storage or disposal facility.

The approach used to check that disposed wastes are consistent with the WAC is based on three pillars:

- *Acceptance criteria*: minimum requirements non-conditioned and conditioned waste must meet.
- *Qualification process*: ascertains that treatment and conditioning processes, a radiological characterization methodology, and/or primary waste packages meet all requirements which have to be fulfilled to produce radioactive waste that complies with applicable WAC.
- *Acceptance process*: verifying the conformity of radioactive waste produced in an approved facility with the applicable WAC.

The assessment of proposals received from the waste producer for the disposal of a specific waste form and their licensing is to be managed in the following steps. (i) The producer of the waste package – after decision has been made on the conditioning technology – prepares a detailed description of each waste type/waste stream. After this, (ii) the operator of the disposal facility (PURAM) decides what of the general WAC is relevant to the given waste type. Considering this, (iii) the waste producer (NPP) prepares the documentation “The waste producer’s verification of the acceptance criteria’s fulfilment”. It contains information about technical and administrative means to ensure the fulfilment of the WAC (“Waste package specification” - WPS).

After this, PURAM develops its own verification system. The document is then submitted for licensing to the Nuclear Regulatory authority. Information about characteristics and features of waste packages is recapitulated in the WPS. A distinct WPS is to be prepared for each waste form and container type.

Each specification should contain the following:

- Details concerning the characteristics of the raw waste.
- Details of the technological steps and regulations ensuring the appropriateness to the criteria.
- The description of the drums and containers and details of the production process.
- The designed and estimated lifetime of the waste matrix and waste package.
- The description of the procedures applied to condition the waste.
- The results of the work accomplished to analyse and verify the waste package’s integrity.
- The summarizing chart that contains parameters deemed to be critical for reaching the required quality of the package, their limit values, or details concerning the acceptance range.

4.5 Italy

The aim of the waste-form qualification process is to demonstrate, on a documentary basis, that the conditioning system has the capability to put the waste into a form suitable for handling, transport, storage, and disposal.

Qualification steps are:

1) ***Laboratory investigations*** – laboratory waste performance simulation tests with non-radioactive (or low radioactive) components are done based on chemical and radiological characterization of the real waste to be conditioned.
2) ***Preliminary solidification study*** – waste pre-treatment studies and concrete formulations studies are performed for determining the best solidification process.
3) ***Pre-qualification tests*** – some preliminary tests (compressive strength, thermal cycling and leachability) are performed to determine if the concrete formulation is suitable.
4) ***Qualification tests*** – other tests are done (immersion, gas generation, etc.) according to national normative and regulatory body indications and criteria, to determine waste-form stability and durability.

4.6 Japan

The safety verification is carried out by the inspection institute in consideration of the manufacturing methods of the packages provided by the operator. Previously, the regulating authorities notified the Nuclear Safety Technology Centre (NSTC) about the procedure that stipulates the details of the verification, because NTSC used to be an appointed institute for the verification. Since the establishment of JNES, the verification job has been transferred to JNES by law. The scheme of safety verification is shown in Figure 4.

At the present time, JNES not only has carried out waste safety verification as an inspection institute, but also has been in charge of evaluating the competence of technical requirements for new waste packages and examining the continuous use of the SF. The flow of this job for new waste safety verification is explained below.

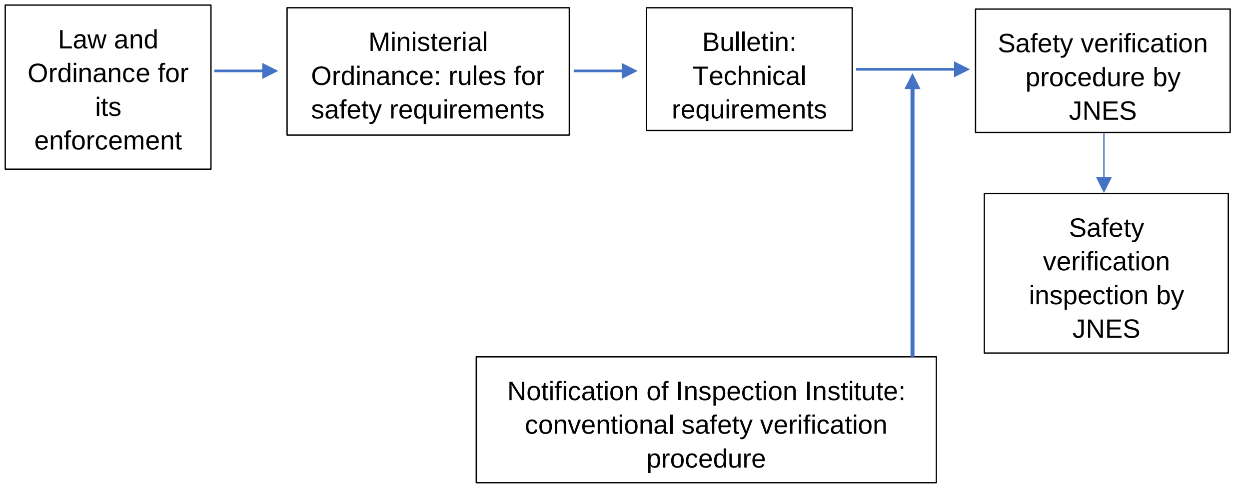

Figure 4: The scheme of safety verification in Japan.

First of all, an operator requests JNES to evaluate the adequacy of a proposal for continuous use of the SF or a method for verifying a new waste package, and then JNES internally starts examining the request. In the process of examination, JNES asks experts for their opinions in an advisory committee set up in JNES for technology of waste safety verification, and results of the investigation are disclosed to the operator and, at the same time, made available to the public. In addition, JNES reports to the regulating authority about the results of investigation. The operator shall apply for actual waste safety verification in accordance with the procedures whose adequacy has been verified by JNES. JNES inspects the waste safety verification and issues a certificate of safety verification when the waste package meets the technical requirements.

4.7 Slovakia

The waste form qualification process has to be supported by a safety assessment. Parameters used as inputs in safety evaluation must be checked for the proposed waste form. JAVYS, a.s. (as a repository operator) submits to ÚJD SR updated 'Limits and conditions for repository operation' including WAC, considering the waste form described and specified for approval.

The RWM is elaborated in detail in the process and operational documentation so as to ensure compliance with the requirements of ÚJD SR Decree No. 30/2012 Coll.

Prior to starting the RWM itself, it is necessary to characterize the physical, chemical, and radiochemical properties of a considered RW type. This information is documented in a passport issued for each waste package which is handed over together with the RW through the individual stages of activities relating to its RWM.

Before repository commissioning, operational procedures are elaborated which consider relations between individual steps of RWM; they might be revised during operation, if appropriate.

Procedures, principles, and instructions for processing operational documentation are described in detail in relevant directives and guidelines of the quality management system. Every operational document passes through annotation and approval process in particular concerned departments and at the end, it is approved by the top management of the organization. The same procedure also governs the process of changes and amendments of individual documents:

- operational documentation,
- documentation of inspections and testing of equipment, and
- technological and working procedures for maintenance.

Results obtained during these activities are reflected into modifications of such procedures as well as to modifications in limits and conditions.

The "Type catalogue of radioactive waste"[1] provides basic information for the labelling and categorization of RW during its packaging and transfer or acceptance for treatment and conditioning in the relevant technological facilities. The document also defines principles and conditions for RW acceptance. Waste must be treated and conditioned so as to meet defined requirements for creating a product which would comply with criteria for permanent disposal in the near surface repository Mochovce.

The RWM process is documented in all stages and information recorded in the waste passport. RW characterization consists in determination of its physical, chemical and radiological properties. This allows for selecting a suitable processing procedure and for the verification of the compliance of generated waste with safety requirements.

The licensee collects and analyses witness samples for the documentation and evaluation of the RWM procedure which are stored until the waste is accepted to the repository. The characterization samples from repository operation are preserved until the end of repository operations.

4.8 Sweden

There are two important basic elements in the Swedish Waste Management Process; Waste Acceptance Criteria (WAC), and Waste Type Descriptions (WTDs) for different waste streams. WAC must be developed by the licensee for the disposal facility, based on an appropriate facility-specific safety case and associated safety assessments. WTDs must be developed by the licensee of the activity or facility where the waste is generated, e.g., the operator of a nuclear power reactor. The WTDs should provide an account of all the steps involved in the process from waste generation up until the final conditioned waste package is delivered to the disposal facility, and thus ensure

[1] This document is regularly updated, usually in two-year intervals (the last update was in 2019)

conformity with the relevant WAC. Among other things, the WTDs need to consider the type of waste package to be used to ensure conformity with the handling equipment at the disposal facility. Another important consideration is the potential restrictions imposed by, e.g., transport regulations and radiation protection. Figure 5 provides an illustration of the waste management process, including waste acceptance relations.

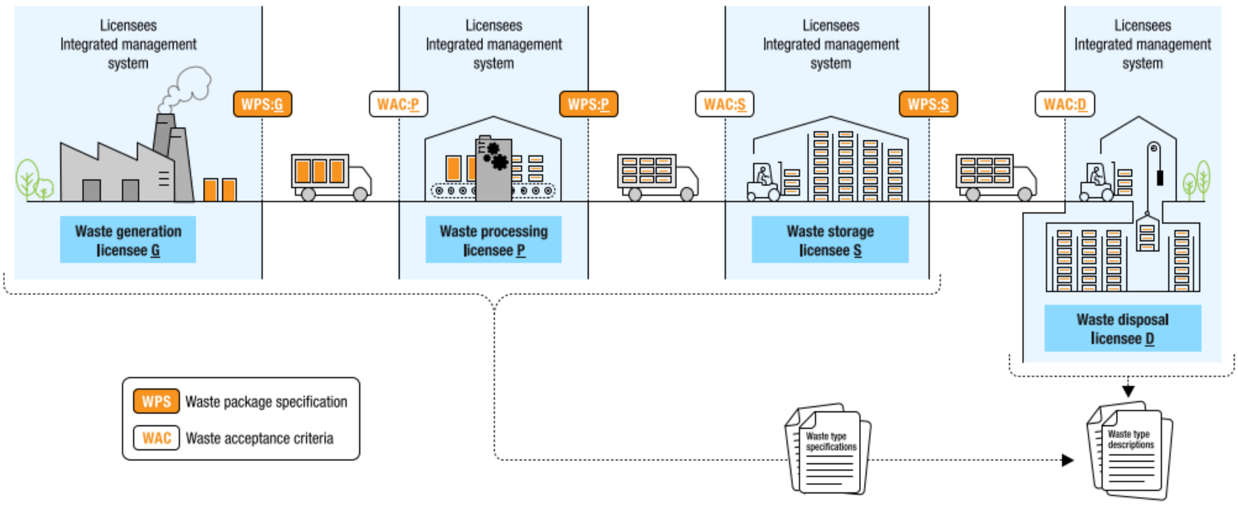

Figure 5: Illustration of SKB's Waste Management Process showing WAC compliant handover stages (Government Offices of Sweden, Ministry of the Environment, 2020).

The WTDs include an overview of the origin of the waste and the handling sequence, detailed descriptions of properties and characteristics of the waste, including the material codes, type of packaging and treatment methods, etc. In addition, the WTDs explain how the wastes meets the WAC in all steps of the handling sequence. This documentation includes a description of production data, results from investigations and calculations as well as checks that are in place. Descriptions of the controls on packaging, the waste form and the waste package are also given. Waste type descriptions are determined for each waste type to be disposed before disposal starts.

To fulfil the obligations in the licences to operate the nuclear facilities SKB has defined a Waste Management Process as one of the main elements in its management system. All other licensees, i.e., waste producers whose radioactive wastes SKB receives and eventually disposes of, must align their waste management activities with this process. The process is supported by the application of WAC: all handovers of waste in the overall waste management process must comply with the relevant WAC. The process is documented by keeping records of all generated waste.

In order to increase the understanding of the process, WAC and other SKB controlled and shared central documents, SKB has set up joint committees with all major waste producers, primarily the nuclear power plants. In addition to the central documents, each waste producer performs a breakdown of the Waste Management Process into underlying instructions, which are part of the individual producer's management system.

The central, SKB-controlled and shared documents in the Waste Management Process are:

- A *Waste Handbook*, that describes the Waste Management Process. In the handbook it is stated which information SKB needs in the specifications from the waste producers and what information the WTDs must contain.
- *Waste Acceptance Criteria*. This document is owned by SKB and stipulates the WAC applicable to SKB's repositories. All waste producers using SKB's repositories are obliged to follow these WAC.

In addition, SKB controls the WTDs which are set up with every waste producer individually. These are essentially safety reports for each waste type from each waste producer and cover all steps in the waste management process (waste generation, conditioning, storage, transportation, reception and operational safety in the repository, and post-closure safety) and provide verification of WAC. SKB produces these documents using specifications from the waste producers covering the initial steps (i.e., waste production, storage and transportation).

The Waste Management Process is regularly evaluated by SKB together with the interested parties, including the waste producers, to ensure that safety is not compromised. In addition, SKB regularly audits the handling of radioactive waste at the nuclear power plants and other waste producers to ensure compliance with the waste management process. These audits are defined as ‘process function audits’ that complement the waste producers’ internal audits.

Regulatory review of the ‘waste management process’ is central in SSM’s regulatory activities. In addition to baseline inspections of waste management activities, SSM reviews the WAC documents developed by SKB as well as the WTD documents developed by the nuclear waste producers.

All waste types must be approved by the regulator before disposal. Compliance with regulations is verified by inspections carried out both at the waste producer and the operator of the disposal facility. These inspections typically cover administrative routines, documentation, equipment, and radiological measurements.

4.9 Switzerland

Waste documentation must contain all the information required for planning the repository and providing the technical and administrative basis for future waste acceptance into the repository. This includes:

- Waste package type specification, which takes into account the conditioning process, the results of prototype testing and issues from quality control and waste characterisation programmes.
- Individual waste package documentation, which consists of a waste package datasheet that includes process data and the results of a quality control programme as well as results from the radiological waste characterisation programme.

The waste package type (WPT) is a conceptual ensemble of similar waste packages (i.e., similar waste producers, raw wastes, binding materials, containers). The WPT specification is the starting point for planning waste production and consists of a technical document in which the waste producer describes and specifies aspects of the (planned) waste packages of the corresponding WPT:

- Manufacturing conditions (process, conditioning procedures)
- Structure and properties of the package and its components (nominal, bandwidths, guarantees)
- Quality control measures
- Provisional radiological inventory
- Datasheet specimen which defines binding declarations in the datasheets of the individual waste packages to be produced

For each WPT specification, the acceptance procedure consists of the following steps:

- The provisional disposability certification procedure which is initiated when prototype testing is required following the development of a new conditioning process. The resulting certificate is based on the provisional assessment of the conditioning process by Nagra, the provisional WPT specification, the prototype testing programme, and the planned quality control programme.
- The disposability certification procedure, where Nagra
    - definitively accepts the various components of the WPT specification (definitive within the existing flexibility of the respective status of the repository licensing step)

  - concludes binding agreements with the waste producers regarding the quality control programme and the radiological waste characterisation programme
  - confirms that the WPT can be integrated into the Swiss disposal concept (and the WPT will be taken into account when the disposal concept is subject to changes)

This results in a disposability certificate with a corresponding technical assessment for the WPT.

- The pre-acceptance procedure which is intended to confirm that the individual waste packages conform to their WPT according to the declarations in their datasheets.
- The acceptance procedure leading to actual emplacement of packages in the repository.

Various tools have been developed for the waste acceptance and disposability assessment and are continually updated to take account of new information:

- The computer-based Information System for Radioactive Materials (ISRAM) is used by the Swiss waste producers and Nagra to present the structure and characteristics of waste package types and to create and manage the individual datasheets for the waste packages
- Detailed procedural rules for the disposability certification and pre-acceptance
- Repository-specific provisional waste acceptance criteria (P-WAC)
- A **Si**mplified **S**afety **An**alysis (SISAN) tool used in the disposability assessments

4.10 UK

For higher activity waste (HAW), which is stored pending availability of a GDF, WAC or more commonly “Conditions for Acceptance” (CfA) are defined for individual storage facilities by the operators (e.g., Sellafield Ltd for the Encapsulated Product Stores and DSRL for the Interim Drum Store). There are currently no final WAC for the disposal of HAW, since a disposal route is not yet available. In the meantime, the UK has developed and applied an extensive system of generic ‘WAC’, which is integral to its national approach to radioactive waste management for waste destined for geological disposal. Their application enables waste conditioning (including packaging) to progress despite the relatively long lead times for siting, developing, implementing and licensing a GDF. A summary of their scope and application follows:

RWM produces packaging specifications and associated guidance as a means of providing a baseline against which the suitability of plans to package waste for geological disposal can be assessed. Collectively these are referred to as the Waste Package Specification and Guidance Documents (WPSGD). These are generic in the sense that they are not specific to a particular disposal facility or site. They make no assumptions regarding the geographical location of the GDF, the geological environment in which it will be constructed or the specific geological disposal concept which could be adopted. They are defined as a precursor to facility specific WAC and may also be regarded as preliminary WAC for the GDF.

Proposals by waste producers for conditioning and packaging HAW are assessed against these generic waste package specifications through several iterations and require endorsement by RWM before operations can proceed. This is known in the UK as the Disposability Assessment process. A successful assessment results in the award of a Letter of Compliance (LoC). Figure 6 summarises the role of the Disposability Assessment process in permissioning stages for a typical waste conditioning plant (see https://rwm.nda.gov.uk/publication/wnm-pp-011-letters-of-compliance-loc-assessment-process-1-january-2008/?download):

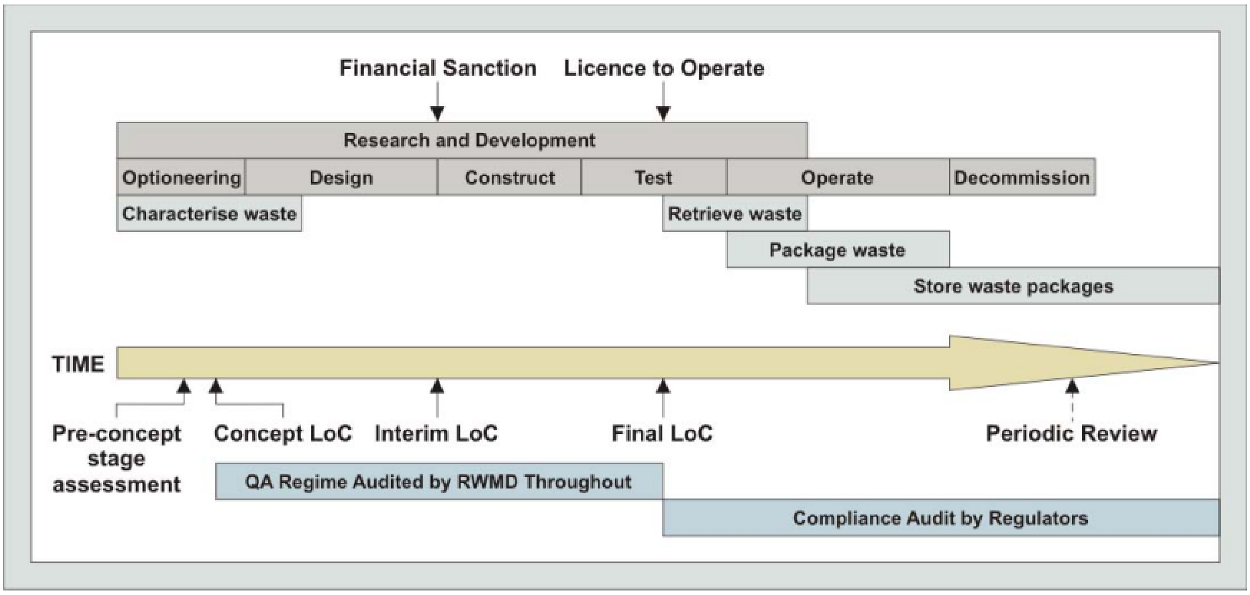

Figure 6: The scheme of the Disposability Assessment process.

The packaging specifications (which were recently restructured) form a four-level hierarchy:

- The Disposal System Specification Part A defines the high-level requirements for the Disposal System (see https://rwm.nda.gov.uk/publication/geological-disposal-disposal-system-specification-part-a-high-level-requirements/).
- The Disposal System Specification Part B defines the technical specification for the Disposal System (see https://rwm.nda.gov.uk/publication/geological-disposal-disposal-system-specification-part-b-technical-specification/).
- The Part C Specifications define the envelope in which to develop new waste package designs for their chosen category of waste.
- The Part D Specifications detail existing container specific requirements.

Guidance provides supporting information and considerations to ensure the requirements in the Part C and D Specifications are achieved. Further information, including specification and guidance documents can be found here: https://www.gov.uk/guidance/creating-standardised-waste-packages.

The generic packaging specifications define the standard properties and performance requirements for waste packages to be compatible with the anticipated systems and safety cases for transport to and disposal in a GDF. The packaging specifications can also be described as the requirements that the waste package and waste form need to meet to minimise the chances that they might not comply with eventual GDF facility WAC. In this regard, the Disposability Assessment process can be considered a risk management approach. Following this process, and utilising the supporting guidance, should greatly reduce the risk of packages requiring rework once a GDF becomes available. It is recommended that UK waste producers should maintain a continuing dialogue with RWM, as the prospective GDF operator, especially when establishing and updating store WAC, updating Radioactive Waste Management Cases (RWMCs), and developing store safety cases. Engagement with RWM should occur at an early stage of the development of a storage system, and with any emergent disposability issues.

In Scotland, HAW packages are also assessed via the Disposability Assessment process. The Scottish Environment Protection Agency (SEPA) currently advises that any waste suitable for disposal will also be suitable for long–term storage in accordance with Scottish Government policy. Work is ongoing at RWM to ensure further consistency between the Disposability Assessment process and Scottish Policy.

The packaging specifications are reviewed and updated when the need for a design / technical change is identified. Review of proposed changes is managed via the Change Control Process and overseen by the Change Control Working Group (CCWG). For example, in 2016 the WPSGD were updated because of changes to the generic GDF design. The WPSGD can also be updated when the Disposability Assessment Process identifies a new container / packaging solution. All directorates within RWM (e.g., Engineering, Waste Management, Safety Case, etc) are engaged when proposing updates to the WPSGD via Change Control, so that implications across the organisation can be evaluated. External stakeholders have been involved as well, e.g., via workshops / meetings for review and feedback with regulators and waste producers. Overarching updates to the system are also periodically made. RWM recently reviewed the scope of the WPSGD with a view to improving its usability, clarity of messages, and to create a better structure of the suite and documents.

5 GENERIC WAC

Another objective of the Task is to synthesize WAC related practices and challenges in a Deliverable "Guidance on formulating generic waste acceptance criteria" based on information from selected countries compiled by Task Partners.

The national analyses were received from countries with different state of development of radioactive waste management. Some countries have no solution for radioactive waste disposal as yet, some have legacy sites, and there are some countries with a well-developed concept for RWM and disposal. Even those countries with a viable solution may face challenges in the form of new waste types, new regulations, or new needs for repositories.

One specific area of interest is the basis for deriving generic WAC. During the development of WAC for disposal, identification of the functions of the components of the disposal system and other constraints, and key parameters relevant to the facility safety case, design and operation should be considered. Collaboration of the three primary actors (waste producers, repository operator, and regulator) on the topic of WAC as early as possible is vital.

The lack of necessary information about waste, particularly legacy wastes, may hamper the development of WAC. Waste generators have a responsibility to provide the basic information about their waste. Those WAC that are derived on the basis of safety assessment are very sensitive to the waste parameters. Improper or lacking information may later force the waste producers to store their waste and dispose them in a more costly repository.

Beside the radiological characterization, non-radiological characterization plays an important role, since there is a growing recognition of the need for improved understanding of the nature and quantities of the likely chemical-toxic component of radioactive waste streams.

In the Table 9, the possible challenging issues are listed as derived from the compiled feedbacks.

Table 9: Challenging issues regarding WAC development.

	Possible concerns
Concept	Philosophy behind the WAC: – not clear – not documented
Regulatory aspects	Uncertain regulatory approach for regulating radioactive wastes mixed with non-radiological hazardous substances. The regulations concerning radioactive waste and chemically toxic waste may be inconsistent.
Interdependencies between different steps of waste management	This question represents a key issue with regard to the interdependencies between different steps of waste management, i.e., between the planning of waste treatment and waste disposal facilities being conducted in parallel. In case of substantial discrepancies between generic and site-specific WAC for the disposal facilities, severe issues could arise for the overall programme if waste treatment facilities have been planned and possibly already constructed based on the generic WAC.
Methodologies of WAC derivation	Countries lacking firm basis to determine WAC may be tempted to "copy" WAC values of other countries.
Waste inventory	Lack of reliable inventory (or inventory with high uncertainty); difficulties in retrieval and restoration of waste inventory records for existing storage and disposal facilities.

	Possible concerns
Wasteform characterization	Lack of characterization methods may represent an obstacle to compliance with WAC: - technical difficulties in characterising conditioned radioactive waste, - sampling methodology and suitable measuring devices may be unavailable, - uncertainties associated to the methods currently used in radioactive waste characterization, - presence of hazardous substances in the waste may make it difficult to measure the mass of specific materials or chemical species.
Waste package characterization	Uncertainties associated with the methods currently used in radioactive waste characterization.
Safety Assessment based WAC	Conservatism vs. realism; definition of rational and possible levels of safety requirements
	Managing of heterogeneity. Scenaria for DSRS disposal.
WAC demonstration and compliance verification	Destructive analyses of waste for the verification of compliance with WAC may be very costly and time consuming.
Managing non-compliances	Treatment of non-conformances may lead to modification of WAC or modification of operating procedures.
Waste tracking	Changing to waste tracking; data imported from a previous tracking system are not verified or are lost (corrupted).
Interfaces between the actors	Waste producer interface with organisation responsible for waste processing and waste disposal operator on WAC is not well established (or does not work properly).

In some countries the term 'generic' WAC is used while other countries prefer the expression 'preliminary' WAC. The former usually indicates that WAC were formulated without any information about potential disposal solutions while the latter builds on information from, at least, a conceptual design of a repository.

The ROUTES project distinguishes these two terms similarly (see EURAD - Milestone 88 - Current use of Waste Acceptance Criteria in European Union Members States and some Associated Countries)

- Generic WAC are not specific to a particular disposal facility or site but are defined as a precursor to facility-specific WAC, in order to enable waste conditioning and packaging to progress in the meantime.
- Preliminary WAC will be developed and updated as planning and implementation of the associated disposal facility progresses.

A short description of generic/preliminary WAC in selected countries is provided in the following sections.

5.1 Australia

Generic Waste Acceptance Criteria have been developed for LLW and ILW waste packages to aid disposal facility (NRWMF) design. They form an important component of the NRWMF safety system and will be revised and further developed once a specific site is selected. The WAC are a living document to be revised and updated for the NRWMF site licensing process and throughout site operations.

The generic WAC consist of the following set of requirements:

Physical requirements

The waste package is the wasteform and the waste container in combination. There are requirements common to all waste packages:

- Wasteforms (the physical form of the waste following treatment/conditioning) must be physically solid and stable, non-reactive and non-flammable, and resistant to degradation.
- Containers with liquids are not accepted at the NRWMF.
- Wasteform volume will be minimised (through waste treatment before packaging and/or by volume reduction using compaction).
- To confirm the source of waste packages and the contents, a unique waste package identifier/ barcode will be placed at two separate locations on the waste container surface.
- Waste packages to be stacked shall use waste containers designed for that purpose.

There are waste type specific requirements:

- For ILW: waste package identifiers are to be readable for an extended period of around 50 years and includes all disused sealed sources and Safeguards material as well,
- For ILW: container shielding can be used to comply with radiation dose requirements and includes all disused sealed sources and Safeguards material as well,
- For Safeguards material: the approval of the Australian Safeguards and Non-proliferation Office (ASNO) approval is required for conditioning; Safeguards material shall be available on request for international inspection.

Chemical requirements

WAC require that all LLW and ILW waste packages are chemically stable and safe for disposal in the LLW vaults. Furthermore, WAC require limitation of chemicals with harmful properties and prohibit dilution with non-waste material to meet WAC.

Controlled substances include those with reactive, explosive, oxidising, corrosive, chelating, chemotoxic and hazardous properties. Related requirements are intended to make such materials passively safe (i.e., no human intervention should be needed after packaging).

Radiological requirements

The radiological requirements include common requirements for LLW and ILW waste package surface contamination (≤ 4 Bq/cm^2 beta-gamma and ≤0.4 Bq/cm^2 alpha) to ensure surface contamination is very low.

Dose rate requirements for ILW and LLW transport packages are:

- Non-exclusive use - restricted to ≤2mSv/h on surfaces, and ≤0.1mSv/h at 1 meter distance.
- Exclusive use - restricted to ≤10mSv/h on surfaces, and ≤0.1mSv/h at 1 meter distance.

Activities of selected radionuclides in waste shall also be measured.

Package record requirements

WAC specify that records are kept for every waste package, and that these are linked to a unique identifier on the surface of each waste package. The recorded information will be used to confirm and validate the safety assumptions used in the safety cases for the operational phase and the post closure phase. These requirements also allow waste packages to be tracked so that, if needed, a package can be retrieved for operational reasons.

The waste package records required are:

- the unique ID of each waste package,
- the consigning organisation/person and the date of transfer from consignor to the NRWMF,
- the weight of each waste package,
- a description of the physical, chemical, structural and biological properties for each waste package and the details of conditioning and packaging,
- content of controlled substances (must be WAC compliant), description of the substances and details of treatment,
- the total activity and the reference date, the activity concentration of reportable nuclides and the reference date,
- the contact dose rate and measurement date,
- contamination clearance certificates showing surface contamination and measurement date
- the number of discrete disused sealed sources in the waste package - drawings and schematics of the sources, shielding and packaging material - source registration certificates / references for the sources in the package, including expired certificates or a declaration from the waste holder with the required information,
- decay calculations that demonstrate whether the disused sealed source will decay to Exemption Levels within 300 years,
- a nuclear safety assessment, and
- reporting information for Safeguard materials.

5.2 Belgium

Preliminary WAC were developed by the WMO (ONDRAF/NIRAS) in accordance with the General Rules for the establishment of acceptance criteria for conditioned waste (CW) around 2000 and for non-conditioned waste (NCW) around 2010. Currently, these WAC are still linked to a generic surface disposal facility. However, they will be revised based on specific characteristics of the planned surface disposal facility in Dessel once available. WAC for waste with the surface repository as the reference destination will be formulated with regard to the technologies for waste treatment, conditioning and storage. WAC for disposal of LLW currently consider exclusively conditioning via cementation.

- WAC have the form of an ONDRAF/NIRAS note.
- WAC are approved by the CEO of ONDRAF/NIRAS after formal advice by the Review Committee of Acceptance Criteria (RCA).
- The Belgian nuclear safety agency (AFCN/FANC) does not have direct control over WAC, which are legally the sole competence of ONDRAF/NIRAS. However, the AFCN/FANC can exercise an influence on the WAC by the assessment of the General Rules proposed by ONDRAF/NIRAS and in the process of approving safety reports and licenses of nuclear installations.
- A permanent technical committee (CTP/VTC) is established by Law to represent the waste producers in matters regarding the WAC.
- WAC are adopted by the CTP/VTC and take effect after being referenced in the waste transfer contracts of the concerned waste producers.
- WAC may not discriminate between waste producers.
- Future legislation is expected to enhance the legal status of the General Rules.

WAC concerning the radiological characteristics of the waste

- Activity content (related to the national waste classification scheme) including, e.g., activity concentration, concentration of alpha emitters and beta-gamma emitters:
- For NCW, CW and disposal waste: Maximum limit to the total activity of Ra-226 and Th-232 per unit of mass (because radium/thorium-bearing waste will be managed separately)
- For NCW: Maximum limits to the total activity and activity concentration of alpha, beta/gamma emitters
- For CW: Maximum limits to the activity concentrations of 28 specific nuclides

- Maximum limit to the radiological heterogeneity factor,
- Radionuclide inventory (relating to transport, operational and post-closure safety): Obligation to specify the activity of 63 standard radionuclides
- Nuclear criticality, in terms of mass limits on fissile material, fertile material, potential moderators (including water) and poisons:
- For NCW, CW and disposal waste: Maximum limits to the masses of U-235, Pu-239 and Pu-241and highly enriched uranium
- For NCW: Obligation to declare the presence of any Special Nuclear Materials

WAC concerning the physical, chemical and biological characteristics of the waste

The chemical parameters specified in the WAC depend on the destination option, as follows:

- for interim storage - stability of the wasteform is specified
- for the future near surface disposal facility - stability of the wasteform (no perturbations of the EBS), complexing agent limitations and cement fraction are imposed
- for a geological disposal facility - no/little perturbations of the disposal system are permitted: gas production (mainly by metal corrosion), heat production, swelling of the waste and the presence oforganics (formation of complexing agents) are limited.

Waste constituents (e.g., in terms of flammables, explosives, free liquids, biological or toxic materials, complexants, water-soluble chlorides and sulphates, other aggressive chemicals, …):

- For NCW, CW and disposal waste:
  - Obligation to specify the waste typology (represented by a code)
  - Obligation to specify H-statements, identify associated hazardous materials and specify mass of each involved hazardous material.
  - Physically hazardous materials (flammable, explosive, aggressive chemicals) are prohibited.
  - Obligation to identify complexing or chelating agent and specify mass of each involved agent
  - Obligation to identify electropositive metals and specify mass of each involved metal. The operator will take specific measures in case the waste contains electropositive metals.
  - Maximum limit to the content of water-soluble chlorides and sulphates (if waste destined for surface repository)
  - Putrefiable materials are prohibited (except for cellulose-containing materials, which are limited to a maximum mass)
  - Concrete rubble must be insensitive to ASR (alkali-silica reaction) and to DEF (delayed ettringite formation)
  - Free liquids are prohibited (evidently not in the case of liquid NCW)
  - Biological pathogens are prohibited
  - Sealed sources are prohibited (sealed sources have a specific management route)

- For NCW: Obligation to give a breakdown into waste fractions and specify waste typology and mass of each fraction.
- For NCW and CW: Obligation to identify absorbents and specify mass of each involved absorbent.

In the case of conditioned waste: the matrix and immobilisation method (e.g., solidification, encapsulation, embedding, …):

- The waste form must be solid, compact, not easily dispersible and chemically stable
- Only cementitious matrices are (presently) considered
- Only embedding (heterogeneous conditioning) and solidification (homogeneous conditioning) are (presently) considered
- Raw materials (cement, granules, additives, water):
  - Must comply with specific standards

    - Additives may not be organic (except for naphthalene sulfonate, polycarboxylate or melanin sulfonate, which may only be used if there is no inorganic alternative)
    - Granules must be insensitive to ASR
    - The origin of raw materials may not be changed without prior notification

- The fresh matrix (in case of heterogeneous conditioning) or matrix-waste mixture (in case of homogeneous conditioning):
    - Must comply with a specific composition, including standard dosing accuracy
    - Must have a specific consistency

- The hardening matrix (in case of heterogeneous conditioning) or matrix-waste mixture (in case of homogeneous conditioning):
    - Must be protected against excessive loss of water by evaporation
    - Must remain immobile
    - May not exhibit free water at the surface (a sign of low quality)
    - May not show signs of segregation
    - Maximum limit to shrinkage

- The hard matrix (in case of heterogeneous conditioning):
    - Must be homogeneous
    - May not exhibit through-going fractures
    - Must be free of DEF
    - Must be resistant to contact with water
    - Maximum limit to the water-accessible porosity
    - Minimum limit to the compressive strength and to the statistical distribution of the compressive strength (should be predictable)
    - Minimum limit to the tensile strength

- The waste form (in case of homogeneous conditioning):
    - Must be homogeneous
    - May not exhibit through-going fractures
    - Must be free of DEF
    - Must be resistant to cold
    - Must exhibit good leaching qualities
    - Must exhibit good ageing qualities
    - Must be robust with respect to raw/treated waste variations
    - Maximum limit to the water-accessible porosity
    - Minimum limit to the compressive strength
    - Minimum limit to the tensile strength

WAC concerning the waste package

For interim storage, the mechanical strength of a drum (also after 75y of storage) must exceed a prescribed value. For the future surface disposal and geologic disposal facilities, the mechanical strength provided by disposal package has a minimum value.

- Container type and material: For NCW, CW and disposal waste: Container type (including material) must be qualified for the waste type
- Dose-rate limits (as related to national waste classification scheme): For NCW, CW and disposal waste: Maximum limit to the dose rate
- Surface contamination (radioactive and non-radioactive e.g., salt deposits): For NCW, CW and disposal waste: Maximum limit to the total activity of alpha, beta/gamma emitters per unit of surface (removable contamination only)
- Thermal output (as a limit to the amount of waste in a single package): For NCW, CW and disposal waste (if applicable): Maximum limit to the thermal power density
- Chemical durability: For NCW and CW: Package components must be chemically compatible
- Void spaces (voidage): For CW: Maximum limit to the empty space

- Waste package stacking and impact performance: No specific criteria (aspect is covered by qualification of container type)
- Waste package fire performance: No specific criteria (aspect is covered by criteria on total activity content)

WAC concerning underpinning information requirements and process quality management

- Waste characterisation / treatment requirements
- For NCW: Covered by the qualification of the radiological characterisation and the qualification of the waste production method .
- For CW and disposal waste: Covered by the qualification of the radiological characterisation and the qualification of the waste (treatment and) conditioning process.
- Component pre-fabrication (e.g. components of the waste container)
- For NCW, CW and disposal waste: Covered by the qualification of the container
- Plant / infrastructure set-up:
- For NCW: Covered by the qualification of the waste production method
  For CW and disposal waste: Covered by the qualification of the waste (treatment and conditioning process)

WAC concerning documentation of waste management

- ID / labelling

  For NCW, CW and disposal waste: Each waste package must be marked with a unique ID code and labelled with warning signs for ionizing radiation

- Other QA / QC requirements

  For NCW, CW and disposal waste: Other QA/QC requirements are covered by the qualifications

- Data management

  For NCW, CW and disposal waste: The unique ID code links the waste with its documentation (which is a data record with a standard list of items)

5.3 Bulgaria

The acceptance criteria are established according to technical, mechanical, chemical, physical, radiological, biological and special organizational requirements which ensure that the received RW is in full compliance with the specific legislation and general approach for RAW management in Bulgaria. The criteria set requirements towards:

- Categories and subcategories of RW;
- RW by origin and physical condition;
- Limits of total activity, specific activity and radionuclides;
- Limits of fissile materials;
- Packages;
- Requirements related to the waste processing, storage, and disposal.

The current waste acceptance system in Bulgaria covers pre-treatment, treatment, conditioning, and storage stages; disposal WAC are still under development. WAC are defined for all RW types, but they are specific for each facility in operation. For the planned disposal facility, preliminary WAC have been proposed; they are part of its design and safety case.

Specific background and concept

Some background points supported by the regulatory documents are:

- WAC are prepared by the repository operator and approved by the regulatory authority.
- WAC should limit values related to chemical composition, heat and radiation resistance and consider the chemical – mechanical stability concerning the waste form and the packages.
- The release of the radionuclides is limited. The physical and chemical form of the waste and the packages together shall ensure that the likelihood of radionuclide release be reduced as much as possible.
- For accepting RW for storage or disposal, the isotope composition and content should be known so that compliance with the requirements of the licence can be verified.
- Any modifications of WAC must reflect compliance with the repository safety case.

List of parameters included in waste acceptance requirements

General: geometry, dimensions, weight, labelling of the packages

Mechanical properties: mechanical stability, mechanical strength

Radiological properties:

- Radionuclide inventory
- Surface dose rate and dose rate at a certain distance
- Surface contamination

Chemical properties - composition and structure, free liquid, corrosion resistance, gas formation

Other important requirements and parameters:

- Combustibility and fire-resistance: waste forms shall be packaged in such a manner and have such characteristics that the risk of self-ignition is negligible.
- Explosive materials: these are not allowed in the waste.
- Chemical reactivity: substances that might jeopardize the stability of the waste packages or the barrier functions of the repository are not allowed. Complexing agents also shall be avoided as far as possible.
- Leaching: the leaching properties must be in accordance with the requirements for long-term safety of the repository.

5.4 Croatia

The development of criteria to be met while accepting waste is required in every stage of radioactive waste management, i.e., treatment, conditioning, storage, and disposal.

In cooperation with the ‘Fund for financing decommissioning of the Krško NPP’, preliminary (generic) WAC were developed for:

- storage and disposal of LILW, and
- takeover and storage of institutional RW and DSRS

These WAC must be approved by the regulatory body, the Ministry of Interior, in the licensing procedure, i.e., in the process of issuing site and construction permits and approvals for trial and regular operation.

Development of WAC is an iterative process that depends on the level of RW characterization, project development status and safety analysis. The preliminary WAC are conservative and were developed based on the concept of storage and disposal facilities. An initial safety assessment for the Central storage for RW and DSRS was completed. The proposed preliminary WAC affected conditioning / packaging / storage approaches and have been used as input for the conceptual design of storage facilities. The preliminary WAC will be further elaborated as a part of safety case for RWM Centre (storage and disposal facilities).

Preliminary WAC for takeover and storage of institutional RW and DSRS

Institutional RW and DSRS that will be transported to the Central storage for RW and DSRS must meet conditions for transport according to the existing national regulations. Five types of packages were approved for RW transport/storage.

The preliminary WAC for storage of institutional RW and DSRS include the following items:

Radiological WAC

- Radionuclide composition and specific activity It is allowed to store packages containing the following RW categories: (i) Exempt RW, (ii) LLW, and (iii) LILW
- Dose rate on surface of the package and at reference distances
- Surface contamination
- Degradation effects of radiation: RW form must have radiation stability.

Chemical WAC

- RW forms must be conditioned in a way to ensure low leachability of radionuclides and other hazardous substances.
- Free liquid content must be reduced to the lowest level that is practically achievable.
- Corrosivity of RW form must be reduced to the lowest level that is practically achievable.
- Metal containers must be constructed from materials that are resistant to corrosion.
- Chelating and complexing agent content must be reduced to the lowest level that is practically achievable.
- Hazardous constituent content must be reduced to the lowest level that is practically achievable.
- Accumulation of flammable and explosive gases in RW package must be below the lowest explosive limit.
- RW packages must not contain explosive materials.
- RW forms must be chemically compatible with container material.

Physical WAC

- RW packages may contain only solid forms of RW.
- Permeability of RW forms must be sufficiently high to allow gases to be vented.
- Porosity of RW forms must be low enough to minimise the release of radionuclides.
- Homogeneity: RW forms must be evenly distributed in containers
- Density of RW forms must ensure homogeneity and structural stability of packages.
- Void content in RW packages must be reduced to the lowest level that is practically achievable.

Mechanical WAC

- Compressive strength: RW packages must be structurally stable.

Thermal WAC

- RW packages that contain self-ignitable and easy ignitable materials are not permitted in the storage facility.
- RW packages should withstand external fire.

Biological WAC

- The biological properties of RW forms must be such that they do not compromise the integrity of the packages.

Package and labelling

- Waste packages must be uniquely labelled in an adequate manner.
- Only approved types of containers can be used for RW transport and storage

Preliminary WAC for storage and disposal of LILW

WAC for storage and disposal of LILW apply to two types of packages: the metal and reinforced concrete containers (RCC) licensed for transport, storage, and disposal. Further, regarding the storage WAC listed above, the following requirements shall be respected:

- LILW must be resistant to thermal cycles.
- LILW must be evenly distributed in the container. Heterogeneous and unconditioned LILW is not allowed for disposal.
- Density and weight of LILW must ensure homogeneity and structural stability.
- Metal and concrete containers must be approved by the regulatory body.
- Treatment and conditioning technologies must be approved by the regulatory body.

5.5 Greece

Greece has not initiated a disposal programme yet, thus, existing WAC applied at the NCSR “Demokritos” interim storage facility only include dose rate limits. These WAC were developed by the facility operator and established in the frame of licensing by the regulatory authority; an update is envisaged with the development of a new storage facility.

WAC for transport (ADR) apply to all shipments of radioactive materials within the country as well as to all shipments abroad.

The future development of WAC in Greece will consider the following specific items:

Radiological characteristics of the waste:

- Activity content (related to the national waste classification scheme) including, e.g., activity concentration, concentration of alpha emitters and beta-gamma emitters
- Radionuclide inventory (relating to transport, operational and post-closure safety)
- Nuclear criticality, in terms of mass limits on fissile material, fertile material, potential moderators (including water) and poisons

Physical, chemical, and biological characteristics of the waste:

- Waste constituents (e.g., in terms of flammables, explosives, free liquids, biological or toxic materials, complexants, water-soluble chlorides/sulphates, other aggressive chemicals, etc.)
- In the case of conditioned waste: the matrix (e.g., glass, cementitious, bituminous, …) and immobilisation method (e.g., solidification, encapsulation, embedding, …)

Waste package (including the container and any requirements on the waste form and container acting in concert):

- Container type and material
- Dose-rate limits (as related to national waste classification scheme)
- Surface contamination (radioactive and non-radioactive, e.g., salt deposits)
- Thermal output (as a limit to the amount of waste in a single package)
- Chemical durability
- Gas generation (e.g., from corrosion, radiolysis, and degradation of organic material)
- Void spaces (voidage)
- Waste package stacking
- Waste package impact performance
- Waste package fire performance

Information requirements and process quality management:

- Waste characterisation / treatment requirements
- Component pre-fabrication (e.g., components of the waste container)

Documentation of waste management:

- ID / labelling
- Other QA / QC requirements
- Data management

Secondary wastes:

- Requirements on the minimization or characteristics of secondary wastes generated during waste management activities.

5.6 Iran

Preliminary Waste Acceptance Criteria were prepared and approved by the regulator (INRWA) in 2013. The waste takeover procedure was prepared by the operator of a disposal facility (IRWA) and provided to waste generators, namely to the BNPP.

Basic considerations

During operation of the disposal facility inspection of incoming RW packages shall be performed to determine compliance with acceptance criteria and include:

- Availability and completeness of accompanying documentation;
- RW package integrity;
- RW package marking;
- Radiation dose rate on the package surface;
- Value of non-fixed contamination of the package outer surface.

In waste acceptance procedures at the disposal facility, visual inspections and radiation monitoring are performed to determine compliance of the actual characteristics of RW packages with their passport data. Non-conforming waste packages are returned to the waste generator for repacking/reprocessing.

A system shall be established for accounting and keeping documentation on RW handling at the disposal facility, including an accounting of the nomenclature of RW packages, their number, characteristics of RW packages, and specification of their location in the disposal facility.

Waste acceptance procedures and parameters to be demonstrated are described below.

Prior to shipment processes:

- Preparing the WP documents
- Submitting the request for acceptance of WP
- Compliance verification based on WAC
- Sending the transport vehicle to generator's site
- Inspection prior to receipt at generator's site

Waste takeover procedure (plan):

- Inspection at the repository
- Administrative checks
- Visual checks
- Direct measurements

- Cemented waste: the technological parameters of the process shall be controlled and checked to ensure that production of the cement compound meets the prescribed basic quality indicators regarding the following parameters:
  - Specific α, β, γ activity
  - Leaching rate
  - Mechanical strength
  - Radiation resistance
  - Stability to thermal cycles
  - Water immersion resistance

Requirements set for waste form, waste containers and waste packages.

- Total activity of the package, specific activity and radionuclide composition;
- Equivalent dose rate of the package;
- Surface contamination of the package;
- Structural stability of the waste form;
- Water-resistance of the solidified waste form;
- Content of corrosive substances;
- Heat generation;
- Thermal stability;
- Radiation resistance;
- Gas generation;
- Biological stability;
- Content of free moisture in the package;

Conditioned waste packages shall not contain:

- Strong oxidants and chemically unstable substances;
- Corrosive substances;
- Poisonous, pathogenic and infectious substances;
- Biologically active substances;
- Flammable and explosion- and fire hazardous substances;
- Substances capable of detonation or explosive decomposition;
- Substances entering into exothermic reaction with water leading to explosion;
- Substances that contain or are capable of generation of toxic gasses, vapours or sublimates;
- Content of liquid in the package shall not exceed 3%.

In the near surface disposal facility, it is not permitted to dispose:

- High-level and long-lived waste;
- Radioactive waste containing more than 3% of liquid;
- Strong oxidants and chemically unstable substances;
- Corrosive substances at concentrations that may result in corrosion destruction of containers, disposal cells and other components of the waste NSSF;
- Flammable and explosion and fire hazardous substances;
- Substances capable of detonation or explosive reduction;
- Substances reacting with water with heat release and generation of combustible gasses;
- Substances entering into exothermic reaction with water leading to explosion;
- Substances that are able to sublimate, as well as to evolve gasses or vapours in volumes resulting in loss of integrity of engineering barriers; Chemical substances of toxic characteristics, corresponding to hazard class I (extremely hazardous) and class II (highly hazardous);
- Pathogenic and infectious substances;
- Biologically active substances;
- Substances forming complex compounds at concentrations that may sufficiently impact on the processes of radionuclide migration into the environment.

5.7 Italy

Preliminary WAC cover all aspects that play a role in the safe management of radioactive waste. Of particular interest are wastes, waste forms, containers and waste packages.

Waste

All waste characteristics which can pose radiological/conventional risks to humans and the environment are considered. In addition to the radiological aspects, material characteristics that can initiate degradation processes inside the package are taken into consideration (e.g., generation of gas, heat, corrosion, swelling, accumulation of secondary products, etc.). Such processes can compromise the efficiency of the conditioning matrix or container, resulting in a release of radionuclides. Characteristics of the waste that may pose a chemical or biological risk are also taken into consideration. The parameters to be followed and requirements to be respected are listed below.

Excluded materials

These are materials that cannot be accepted for disposal, as they would compromise the stability of packages, repository structures and, therefore, safety of workers and the population:

- Liquid waste;
- Explosive materials;
- Flammable materials;
- Strongly reactive materials;
- Putrescible and infectious materials;
- Pressurized canisters.

Materials accepted with limitations

Some materials will be acceptable to the planned repository with limitations to reduce risks associated with their specific characteristics. The acceptance limits for disposal are defined on a case-by-case basis as a part of the checks relating to the "LoC procedure". Pending the availability of definitive WAC, a procedure has been agreed with the Italian Regulator (ISIN) which foresees the so-called ‘Letter of Compliance (LoC)’, i.e., a declaration issued by the WMO, Sogin, to ISIN related to a waste producer, whenever they submit to ISIN an application concerning the treatment/conditioning of a specific waste stream. The purpose of this declaration is granting the preliminary acceptance of the relevant waste packages for storage/disposal into the repository. To this end, Sogin carries out preliminary assessments and communicates the outcomes to ISIN and to the Producer.

Limitations correspond to the following items:

- Free liquids (<1% of internal volume);
- Absorbent materials;
- Soluble materials;
- Corrosive materials;
- Reactive materials;
- Complexing agents and chelating agents;
- Organic materials, oils, greases and paraffin;
- Particulate materials;
- Compactable materials and/or with cavities (voids reduction);
- Sealed sources;
- Heavy metals.

The quantitative limit of some of these materials (i.e., heavy metals) will be defined only after the Post closure Safety Assessment is available, i.e., once the final design of the NR has been finalized. Such limits will be expressed in terms of total acceptable capacity of the repository.

Waste form

Conditioning matrices must undergo a qualification process and must be of a specific formulation based on the characteristics of waste to be conditioned. The qualification of a conditioning matrix must be performed according to the tests required by the Technical Standards.

Limits indicated for the individual tests of this Technical Standard are in fact the WAC relating to the "waste form" andinclude the following items:

- Compressive strength
- Thermal cycling
- Radiation resistance
- Fire resistance
- Non-combustible or self-extinguishing materials
- Biodegradation resistance
- Immersion performance
- Leaching rate
- Gas generation
- Identification and quantification of gases produced by radiolysis or other chemical physical reactions
- Waste covering
- Water permeability

Containers

The containers will be accepted at the repository if qualified according to the Technical Standards. They must have geometries, dimensions and structures that can be arranged in the repository disposal unit (module). Three types of containers have been approved as "standard containers": a drum and two rectangular concrete containers. The possibility of accepting for disposal waste packaged in other containers shall be assessed on a case-by-case basis as a part of the "LoC procedure".

The quality parameters of containers to be demonstrated are as follows:

- Compressive strength
- Thermal cycling
- Radiation resistance
- Fire resistance
- Biodegradation resistance
- Immersion
- Leaching rate
- Gas generation
- Waste covering
- Water permeability

Waste package

The criteria regarding the final waste forms are established with respect to characteristics related to the waste conditioning processes:

- Activity of each radionuclide;
- Total activity;
- Activity distribution;
- Content of fissile material;
- Voids;
- Weight;
- Dose rate and surface contamination;
- Centre of gravity.

5.8 Lithuania

Lithuania is developing a near surface repository for waste arising due to decommissioning of the Ignalina NPP.

WAC requirements for VLLW and LILW must include at a minimum the following items:

Radiological characteristics of the waste

RW must be classified according to the Lithuanian waste classification scheme. Solid RW is classified taking into account surface dose rates, total alpha activity of long-lived emitters (half-live longer than 30 years), total beta and gamma activity. SNF and spent nuclear sources belong to separate classes.

Typical WAC prescribe the following radiological characteristics of RW packages:

- package activity limits;
- total α, β and γ activity;
- limit values for specific activities of individual radionuclides;
- dose rates on the surface of the package and limit values for surface contamination.

Detailed radionuclide inventories must be declared for treatment, conditioning, packaging and disposal of RW. For transport at the INPP site, non-fixed surface contamination is limited as well.

Physical, chemical and biological characteristics of the waste

RW must be solidified or it must be demonstrated that there is no possibility of its uncontrolled release into the environment. Other hazardous properties of RW (e.g., flammability, spontaneous combustion, explosion, chemical reactivity, biodegradation) that may affect the release of radionuclides from RW must be assessed and analysed regarding their impact on the safety of RW management facilities and compliance with nuclear safety standards.

Combustible LLW will be incinerated, and other solid waste will be compacted to reduce its volume. Such waste will be placed in containers that will be filled with concrete to prepare RW packages for disposal in the near surface repository.

Waste package

The RW storage facility contains cemented wastes: sludge from concentrate tanks, spent ion-exchange resins from INPP water treatment and liquid waste treatment systems, filter materials (perlite) and reactor channel graphite waste. Cemented waste is poured into 200 L steel drums, which are placed into a container with a volume of about 5.6 m^3.

The repository for VLLW will contain standard 20 feet half-height ISO containers with uncompacted solid RW, plastic bundles with compressed RW (about 1 m^3 waste wrapped in steel strips and polyethylene film) and flexible plastic containers (FIBC package of about 1.1 m^3) with spent ion exchange resins.

Contamination of the surface of RW packages and dose rates must not exceed the limits specified in the radioactive WAC specified by the repository operator.

Requirements underpinning information requirements and process quality management

An applicant for a licence for work with radiation sources must justify that all RWM operations, from waste generation to its disposal in a repository, are taken into account, each mutually coordinated.

WAC concerning documentation of waste management

The main documents describing the quality of a waste package are the ‘Packaging description’ and the Passport. The package description shall include the following information:

- Radiological properties of RW;
- Chemical (e.g., chemical composition of materials and their compatibility, hazardous properties, stability to ionizing radiation, etc.), biological (e.g., organic composition of materials, exposure to microorganisms, etc.) and physical (e.g., state of matter, mass, volume of RW), density, etc.) properties;
- Mass, volume, dimensions and load resistance of the packages;
- Place of generation of RW;
- Unique package labelling;
- Quality criteria for packaging and the procedure for checking their compliance with these quality criteria;
- Package passport form.

The ‘Packaging description’ shall:

- Indicate the series of packages for which the description is intended, the description of the compiler of the description, the approval and entry into force of the description;
- Indicate the series of RW packages, sources of RW generation and the class of RW;
- Specify the production of a series of RW packages, the storage, transport to a repository or repository;
- Provide functional requirements for the acceptance of RW. Indicate for which stage of RWM the requirement is restrictive. Express quantitative parameters in numerical values, indicating possible limits of values;
- Provide justification that the parameters and properties of the packaging meet the acceptance criteria for RW. Identify and list the parameters that determine the quality of RW packaging, and describe how they will be inspected and controlled. This description must be such that it is possible to technically assess whether the immobilized RW meets the acceptance criteria for RW;
- Describe the RW disposal facility and the readiness of the operating organization to control the compliance of all identified parameters. This document shall detail the preparation for the inspection of RW packages in accordance with the requirements. This information shall include all actions and resources to ensure that the package complies with the requirements of the national legislation and the ‘Packaging description’;
- Describe the RW, indicating the owner, source, volume (cubic meters) and weight (tonnes);
- Provide numerical data on the measured or estimated radionuclide composition of untreated RW, as well as limit values for general and specific activity, and describe the physical and chemical properties of untreated RW;
- Indicate the activities of radionuclides and other properties that may adversely affect the suitability of the packaging for acceptance at the repository;
- Provide a description of the container that will be used to contain the RW packages, indicating its dimensions, empty weight, material, mechanical and physical properties;
- Indicate the technical conditions of the container production and attach the drawing, certificate and registration code.
- Indicate the filling material of the container and the full weight of the container;
- Provide a technical description of the conditioning process, along with drawings or diagrams to illustrate this description;
- Describe the previous stages of RW treatment, including the initial treatment of the waste (if any) and storage;
- Describe the readiness to control and limit the amount of hazardous substances;
- Determine the amount of fissile radioactive material in the package and show that it does not exceed the permissible limits. Describe the readiness to control the amount of fissile radioactive material in a separate package;
- Describe the preparation for management non-compliant package;
- Provide a description of the immobilized RW, indicating the radionuclide composition, general and specific activities;
- Indicate the chemical composition of the waste and the waste binder, the percentage of voids, the degree of homogeneity and the mechanical strength;

- Present the results of radionuclide leaching and release measurements;
- Provide average and limit values for the characteristics and parameters and general and specific activity characteristics for a particular series of packages;
- Indicate the average and limit values for the weight and dose rate of the packages on the surface of the package;
- Provide packaging evaluation data covering mechanical resistance, resistance to ionizing radiation, fire resistance, emptiness, durability, and leaching of radionuclides;
- Specify the system and methods for registration, marking and coding of packages, providing a unique identifier (digital or bar code) for each package and an electronic data storage form (database);
- Prepare a standard document (packaging passport), which is an integral part of the 'Packaging description';
- Provide all results of research and calculations regarding the container, immobilized RW, and their package;
- Submit the normative technical documents of the organization operating the RW management facility and storage facility, showing how the conformity of the RW packages to the properties specified in the 'Packaging description' is ensured;
- In the absence of standardized test procedures, provide descriptions of test procedures for immobilized RW and its package (e.g., tests for resistance to solubility and leaching of immobilized RW, and tests to demonstrate the ability of the RW package to withstand thermal cycling).

The passport of a RW package shall contain information about properties of the RW and the package, expressed in numerical values. The passport describing each package must contain the following items:

- Package model and construction;
- Package description code;
- Data to establish the identity of the package (code, place of marking, date of manufacture;
- Mass;
- Voids;
- Dose rate on the surface of the package;
- Surface contamination;
- External dimensions.

The description of RW in the passport shall also include:

- Waste origin;
- RW treatment method;
- Volume;
- Chemical composition;
- Density;
- Activities (specific, total alpha, beta and gamma activity);
- Radionuclide composition.

The passport must also contain information about:

- Person (persons) responsible for the quality of the package and the preparation of the package passport;
- Environmental conditions and factory parameters that affect the quality of the package, the limit values and the conformity of the package with them.

5.9 Moldova

Moldova does not operate a repository. However, a centralised long-term storage facility is under development. Generic WAC for that purpose have been formulated andare structured into the four main groups described below. They are further elaborated for waste type, waste form, and for the design of containers for solid waste and DSRS.

Administrative data relating to the identification and the traceability of the waste and waste package, i.e.:

- Identification: Unique waste package identification (barcode) for drum or container
- Operational: Package types permitted for use
- Record keeping: Format and content for waste package specification

Waste package data relative to waste package-specific data such as interfacing, containment and durability, e.g.::

- Maximum dimensions
- Maximum mass of the waste package
- Compliance with handling and transport system
- Maximum stacking height
- Information on tests performed periodically during interim storage of waste, including information on corrosion and any damage

Waste characterization data relative to the waste inventory, its physical form and intrinsic containment properties;

Inventory parameters to be characterized:

- Radionuclide content (list of relevant radionuclides);
- Deviation in isotope composition
- Specific activity of individual isotopes in the solidified waste;
- Deviation (uncertainty) of specific activity
- Total activity of alpha emitters
- Deviation (uncertainty) of activity of alpha emitters
- Total activity of beta emitters
- Deviation (uncertainty) of activity of beta emitters
- Total activity of gamma emitters
- Deviation (uncertainty) of activity of gamma emitters

Waste form qualification

- Only conditioned waste shall be accepted for storage / disposal
- Activity homogeneously distributed in the drums
- Container water tightness

Containment intrinsic properties

- Acceptable waste types / classes / forms
- Restrictions on waste form (e.g., density, permeability, porosity, leach rate)

Safety-related criteria relative to the waste stability, hazardous and radioactive material content and radiation protection are listed in the Table10.

Values of activity limits for waste packages are specified (adjusted) on the basis of the results of safety assessment of the storage facility and the waste packages to be stored. Derivation of activity limits shall take into account the following factors: direct irradiation from a package (it should not present a hazard to the personnel operating the storage/repository and the public), heat releases (it should be negligible), criticality, and maximum radionuclide specific activities.

Additionally, the specified WAC shall be supplemented by the methodology for the acceptance process, including the techniques for verification of compliance with the criteria, and how to deal with non-conformities.

Table 10: The list of safety related WAC.

Stability	Chemical stability of waste form	There are no reactive materials in the waste.
		Specification of compatible materials to prevent or minimize the possibility of chemical reactions between waste and container. Specification of material properties to prevent or minimize the effects of chemical decomposition over time.
	Radiation stability of waste form	Specification or limit on materials to prevent or minimize possible damage to waste forms from radiolytic effects.
	Physical stability of waste form	Specification or limits on void space in waste containers.
	Durability of waste package / container	Specification or limit on materials to ensure adequate corrosion, fire, water, mechanical and impact resistance.
	Mechanical properties of waste form / package	Specification of limits on mechanical properties such as minimum compressive strength and void space in the waste package.
Restrictions on content of waste packages	Restrictions on chemical or other hazardous constituents	Total ban on reactive chemicals, explosive and pyrophoric materials. Total ban on biological, pathogenic, and/or infectious materials. Upper limit on some materials such as corrosive, chelating materials on a per package basis.
	Restrictions on biological, pathogenic, and/or infectious materials	Total ban or upper limit on a per package basis on some materials such as biological, pathogenic, and/or infectious materials
	Restrictions on free liquids	Total ban or upper limit on a per package basis of free liquids
	Restrictions on combustible materials	Total ban or upper limit on a per package basis of combustible materials
	Restriction on gas release	
	Restrictions on heat generation rate	Upper limit on a per package basis of heat generation rate
Radioactivity	Restrictions on radionuclides	Upper limit of activity concentration of pre-defined radionuclides, (e.g., maximum specific activity per waste package)
	Restrictions on fissile content	Upper limit of concentration or total amount of fissile radionuclides
Radiation protection	Restrictions on gamma radiation dose rates	Upper limit of gamma dose rate at contact with and at a specified working distanced from the waste package (e.g., 1 m)
	Restrictions on fixed and/or removable surface contamination on waste packages	Upper limit of contamination of families of radionuclides (e.g., Bq/cm^2 of gamma radionuclides, beta radionuclides and/or alpha radionuclides)

5.10 Romania

The preliminary WAC for the LILW short lived waste to be disposed of in the planned near surface facility were developed with the EC assistance (in the PHARE project). This repository shall accept waste from the operation and decommissioning of the NPP.

The preliminary WAC will be updated once the near surface disposal programme advances in its implementation.

The following types of inert homogeneous or heterogeneous waste are accepted: metallic waste that does not react with water, concrete rubble, pellets of compacted plastics and tissues, sludge, aqueous solutions, filters, ion exchange resins.

The spectrum of acceptable waste is limited by the following restrictions:

- All "substances of very high concern" according to European REACH regulations are considered as toxic chemicals and are accepted with restriction, based on a case by case decision;
- Other waste accepted with restriction, on case by case decisions, are chelating agents, waste which reacts with the matrix, waste which reacts with water (aluminium, zinc, uranium, magnesium), wood, absorbers, liquids into absorbers;
- Compounds which present risks of explosion or ignition, such as alkali metals, powdery magnesium, uranium, aluminium, explosives, unstable chemicals, strong reducers (hydrazine, boro-hydride, fuel, alcohol, phosphorus...) are forbidden for disposal;
- Radioactive sources, infectious or putrescible waste, non-solidified liquids, non-solidified homogeneous waste, non-immobilized heterogeneous waste, waste containing gas are also forbidden for disposal;
- Raw waste is not accepted for disposal: homogeneous waste is to be solidified; heterogeneous waste is to be immobilised: cement matrix is convenient for both cases, other matrixes are possible.

Requirements posed on the waste package, container type and material include the characteristics listed below:

- The disposal container shall isolate the solidified waste for 300 years. This requirement implies that after an underwater immersion period of 300 years, the container is still hermetic and that the leaching characteristics are guaranteed;
- The minimum mechanical strength thickness of an empty disposal container withstands at least a load of 250 kPa;
- When super absorbed liquids are solidified, the producer shall demonstrate that no fluid secretions from the solidified block will occur for 300 years
- Dose-rate limits (as related to national waste classification scheme)
- Surface contamination (radioactive and non-radioactive e.g., salt deposits)
- Thermal output (as a limit to the amount of waste in a single package)
- Chemical durability
- Gas generation (e.g., from corrosion, radiolysis and degradation of organic material)
- Void spaces (voidage)
- Waste package stacking
- The dose equivalent rate at contact of the external surface of the container is limited
- The surface removable contamination of the external surface of the container is limited
- No residual water shall remain after 24 h curing;
- Maximum of 10 % (volume) of voids is allowed, provided that the compressive strength criterion is met.

5.11 Slovenia

Slovenian rules on radioactive waste and spent fuel management specify that the establishment of WAC is a legal requirement. WAC formulation is necessary for the licensing process for storage and disposal facilities: a repository for L-ILW is under development. Requirements related to waste treatment, conditioning and packaging are captured within the WAC for these facilities, therefore, separate WAC for pre-storage activities are not legally requested.

WAC in Slovenia are formulated as follows:

Radiological properties:

- The content and specific activity of radionuclides
- Surface dose rate and dose rates at reference distances from the package surface
- Specific surface contamination
- Degradation effects of radiation

Chemical properties:

- Leachability
- Free liquid content
- Corrosiveness
- Resistance to corrosion
- Presence of chelating and other complex compounds
- Toxin content
- Gas formation and gas content
- Explosive properties
- Chemical stability.

Mechanical properties:

- Structural strength

Thermal properties:

- Flammability
- Combustibility

Biological properties:

- Content of organic substances
- Ban of putrescible/fermenting materials

Physical properties:

- Permeability and porosity
- Homogeneity
- Density
- Presence of voids

Marking and packaging:

- Method of marking packages
- Types of containers and method of packaging

Radioactive waste generated at Krško NPP are subjected to WAC conformance tests involving visual control, surface dose rate and contamination measurements, and a check of valid documentation and labeling.

5.12 Switzerland

Various tools have been developed for the waste acceptance and disposability assessment in a future repository for L-ILW: these tools are continually updated to take account of new information gained through the following channels:

- The computer-based Information System for Radioactive Materials (ISRAM) used in Switzerland
- Waste producers and Nagra (the WMO) define the structure and characteristics of waste package types and create and manage the individual datasheets for the waste packages
- Detailed procedural rules for disposability certification and pre-acceptance have been formulated
- Repository-specific provisional waste acceptance criteria (P-WAC) were developed
- A Simplified **S**afety **An**alysis (SISAN) tool used in the disposability assessments

Conditioning procedures for Swiss wastes and quality assessment measures

All radioactive wastes (except highly activated metals) are solidified. Liquid and dispersible raw wastes (e.g., resins, concentrates, slurries) are mixed with suitable additives to form a homogeneous waste product/matrix. Other solid wastes are simply embedded in the solidification material. Cement is the main material used for solidification, and bitumen and polystyrene are used for resins and concentrates from PWR reactors. The quality of conditioned wastes is ensured by comprehensive quality control programmes during production. In parallel with conditioning, representative raw waste samples are also taken for radiological waste characterisation.

Measures for waste product control

For cemented waste products, the following data are required:

- Compressive strength: After hardening, waste product samples are exposed to mechanical loading.
- Leaching: Leach rates for the key test nuclides Co-60 and Cs-137, tests are performed in demineralised and saturated gypsum water.
- Water (and sulphate) resistance: Investigation of the stability of waste products upon water infiltration. Only when the compressive strength of the sample exposed to an aqueous medium is (still) above 10 MPa and the volume increase is less than 5% is the waste product considered water- (and sulphate-) resistant.

For bituminised and polystyrene waste products, the following data are required:

- Flash, burning, ignition point: Samples (usually inactive simulates) are heated until they begin to flash and burn and escaping gases ignite. This test provides information on the resistance of the waste product to thermal loading.
- Softening point: This test is used to determine the point at which the waste matrix begins to flow and the potential separation of bitumen and waste occurs.
- Viscosity (only bituminised waste products), e.g., determined by needle penetration:
- Leaching: As for cemented waste products
- Water (and sulphate) resistance: As for cemented waste products without the limit of compressive strength

Radiological waste characterisation programme

In parallel with conditioning, representative raw waste samples, e.g., from the NPP cleaning circuits, are taken and analysed. The activity measurements include the following “reference nuclides”:

- γ emitters such as Co-60, Cs-137/Ba-137m, Mn-54, Cs-134, Ce-144/Pr-144
- β and X-ray emitters such as H-3, C-14, Cl-36, Fe-55, Ni-63, Sr-90, Tc-99, I-129, Pu-241
- α emitters such as U-235, U-238, Pu-238, Pu-239/240, Am-241, Cm-244

Based on these measurements, the activities of these and other nuclides that are difficult to measure are related to the activity of the "key nuclides" Co-60 and Cs-137/Ba-137m. Using these "correlation factors", the total nuclide inventory of the waste packages can be determined based, e.g., on gamma scans for Co-60 activity of waste packages.

Wastes from the reactor pressure vessel which have been activated by a significant neutron flux are characterised by activation calculations, which are validated and verified by measurements.

Characterisation of the waste packages

In the final step, the finished waste packages are checked. This checking includes measurement of dose rates and γ emitters, completed with the nuclides from the raw waste characterisation programme. The packages are also checked for:

- free water at the top, which could cause container corrosion, must be removed
- hardening of the waste product
- surface contamination (α, β/γ)

Data recording

All data acquired during the production process and from the product control and radiological characterisation programmes are registered in the ISRAM information system.

Safety-relevant waste properties and contents of the P-WAC

In the post-closure phase of the Swiss repository concept, hydraulic pathways are important for any potential release of radionuclides. The performance of the near-field and the geosphere can, in principle, be perturbed by individual waste properties:

- Some materials or their degradation products may affect the geochemical conditions, resulting in reduced geochemical retention
- (Excessive) swelling or shrinkage can result in fissures in the engineered barriers, leading to preferential flow paths which may result in enhanced nuclide release rates
- Corrosion (of metals) and degradation of (organic) materials can lead to gas generation
- Significant gas generation rates can result in enhanced radionuclide release rates, e.g., due to expulsion of contaminated porewater.

Based on these considerations, the following quantitative and qualitative criteria were developed for the P-WAC.

- No free liquids, no free gas
- No explosive, chemically unstable materials
- Stability/integrity at time of disposal
- Maximum size
- Maximum weight
- Specific heat generation
- Specific gas generation
- Surface dose rate
- Minimisation of swelling/shrinking materials
- Minimisation of voidage
- Minimisation of burnable materials
- Absence of surface contamination
- Waste matrix/product
- Solid/hard waste matrix
- Compressive strength (cemented waste)
- Poor degradability by water (water resistance, low leach rate of nuclides)

6 NATIONAL SPECIFICS

This section summarises WAC challenges of different national RWM programmes as identified in national analyses.

The main challenges arise from missing disposal capacities, approaches to update WAC, and management of legacy waste.

6.1 Austria

Austria has not succeeded in siting a disposal facility and, thus, disposal WAC remains open. The solution shall be found by 2035 which corresponds to the time that all waste (including that from the IAEA laboratories) will be stored in the nuclear research institute in Seibersdorf. Austria participates in EU programmes aiming at the construction of a shared repository.

6.2 Belgium

Belgium formulated preliminary WAC, which shall be revised after inputs relevant to the disposal facility under development are collected. The current work to revise the WAC aims to:

- Improve the structure and the comprehensibility of the criteria (provide justifications, enhance wording and use of terminology)
- Take account of the conformity criteria in the safety report of the Dessel surface repository.

Future legislation is expected to:

- Enhance the legal status of the General Rules
- Install a system of verification by AFCN/FANC (safety authority) that WAC have been established in accordance with the General Rules.
- Install a system of regular evaluation of the WAC by ONDRAF/NIRAS, to take account of experience and the acquisition of new knowledge.

Factors prompting WAC development can be summarised as follows:

- The present WAC for non-conditioned waste were established around 2010, in a campaign to change their format (from so-called “Specifications” to “ACRIA’s”)
- The base set of the present WAC for conditioned waste was established around 2000, following the approval of the General Rules by the competent authority.
- Since 2000, specific WAC have been established whenever a producer announced the generation of a specific type of conditioned waste, e.g.:
    - CSD-C (compacted ILW from la Hague); WAC established in 2006
    - Homogeneous cemented ILW from Dounray; WAC established in 2008
    - CSD-B (vitrified ILW from la Hague); WAC established in 2013

At present, no system of regular evaluation of WAC exists. However, it is expected that this will change in the future.

In general, previous updates were driven by changes of the legal or regulatory framework (e.g., change to the safety report of a storage building, allowing a larger activity concentration of alpha-emitters in CW packages). In general, these updates were limited to one or more criteria.

The establishment and updates of WAC are influenced by waste producers, operators and safety authorities alike.

6.3 Czech Republic

The Czech disposal programme was initiated in the mid-1950s. Currently, there are four facilities for LILW disposal with a relatively small capacity.

Three repositories have been used for institutional RW disposal:

- Hostim (now closed) – two rock cavities used for disposal of institutional RW containing artificial radionuclides
- Richard (operational) – a former limestone mine used for disposal of institutional RW containing artificial radionuclides
- Bratrství (operational) – a former uranium mine used for disposal of institutional RW containing natural radionuclides

The last repository, Dukovany (surface engineered vault type system), was built to accept RW from the operation and decommissioning of NPPs; later, disposal of limited volume of institutional waste was approved.WAC for all repositories were firstly formulated in the late-1980s. Since then, they were updated several times, namely, with regular revisions of safety documentation of all facilities (currently in five-year intervals). WAC were revisited to incorporate new information on RW radionuclide inventory and composition, final RW form, solidification media, and hydrogeological conditions of the site, together with a broader extent of scenarios defined for impact evaluation, in compliance with actual progress in modelling and calculation methods.

6.4 Germany

Currently, there is only one final disposal site, Schacht Konrad, for which WAC were formulated by the Federal Company for Radioactive Waste Disposal (BGE). It is aimed at the disposal of waste with negligible heat generation (or LILW). WAC are based on the assumption that the mine will be (suddenly) flooded, and the accommodated waste will equilibrate with the groundwater. The defined inventory of radionuclides and accompanying compounds must not be hazardous to the groundwater beyond values defined by the Federal Water Act.

Currently, activities towards establishing WAC are accelerated due to the licencing process. WAC are subject to a review / update if deemed necessary considering the state-of-the-art in science and technology. Previous updates of the WAC were caused by specification of waste forms and their radioactive and chemical composition.

6.5 Hungary

The following text describes the evolution of WAC for the near surface disposal facility Püspökszilágy (RWTDF). It indicates how waste acceptance criteria may change over the operational lifetime of a facility.

Neither the original licence nor the licensing of the facility lifetime extension dealt with WAC. It was the obligation of the facility to take over every radioactive waste generated by isotope applications in the country.

Because the original licence did not deal with WAC, high activity sources and DSRSs consisting of long-half life and alpha emitting radionuclides have also been disposed. The lack of defined WAC means that an acceptable benchmark was not established against which the type of waste received could be judged to be in conformance or non-conformance with a required standard other than external dose rate.

The site was extended in the late-1980s. The Hungarian Geological Survey, one of the authorities participating in the licensing procedure, did not consent to the issue of the permanent license during the licensing procedure of the new vaults. The new vault extension has been granted a limited operating license.

During the fulfilment of licensing conditions for the extension, limited work on site specific limits has been carried out as a part of the emergency planning guides, which resulted in formulation of relevant recommendations for future operation of the disposal facility.

For the operational phase the following scenarios were selected:

- quick fire inside the transportation vehicle,
- burning of one layer inside the vault,
- chemical explosion inside the treatment facility.

For the post closure phase, the following scenarios were analysed:

- transport by groundwater and drinking water usage,
- inadvertent human intrusion (road construction).

The most conservative groundwater travel time was used to calculate activity concentrations in the groundwater. Sorption data were selected from the OECD database for best estimate and conservative cases.

Based on these scoping calculations, the following recommendations were made with respect to waste acceptance:

- limit the activity accessible to fire accidents
  - at 1.5 GBq for long-lived components,
  - at 15 GBq for short-lived isotopes,
- the above values do not apply to the activity already backfilled or sealed inside the vaults,
- limit the activity concentration of individual waste packages at the upper limit of intermediate level waste category for the components with half-lives of 5-6 years and less, on the level of $5*10^6$ kBq/kg for isotopes having half-lives of 6-30 years and set additionally the average concentration for the whole facility at the limit of low-level wastes.
- disused sealed sources of Ra-226, Pu-239, Tc-99 and C-14 can be accepted for interim storage only; disposal is not permitted.

In 1998, the new operator of the facility, PURAM, recognized that inconsistencies existed in the recording of waste previously stored at the site. Proposals were made to establish a comprehensive QA/QC system as part of the review of the safety of the repository and derive new WAC, based on the new safety assessments.

In connection with the safety upgrading programme, new WAC were derived.

In 2016 the WAC for RWTDF became a multi-level system: there are separate WAC sets for waste reception, storage and disposal. The takeover, storage and disposal of any institutional radioactive waste became the responsibility of the RWTDF. The waste received from producers without waste conditioning capacity was treated and conditioned in the RWTDF. For this case PURAM developed WAC for takeover and their specification is mostly relying on the international regulations of the transport of hazardous material (ADR) Nevertheless, some considerations based on the intent of storage or disposal have also been included in this WAC set.

Four sets of WAC were developed in case of RWTDF:

- WAC for long term disposal – compliance enables the immediate disposal in a disposal vault. This set contains the most rigorous limits for activity content, physical-chemical properties and packaging.
- WAC for mid-term disposal – the only alteration from the previous WAC is the activity content. This set of criteria is applicable for waste that requires storage for a certain time in the interim storage facility before complying with the WAC for long term disposal.
- WAC for interim storage – this set of criteria is more permissive regarding the activity content, physical-chemical forms and packaging. These criteria are suitable for waste that cannot be disposed of because of the content of isotopes with long half-lives.

- WAC for takeover – most permissive criteria applied for waste from those producers that cannot fulfil the stricter criteria. In this case the treatment and conditioning of the radioactive waste relies on the RWTDF.

6.6 Iran

In the following paragraphs some challenging issues impacting on the formulation of WAC in a programme where waste has already started to be generated (Busher NPP) while a disposal facility is still in its development stage (managed by IRWA, the WMO):

- Responsibilities of different branches of the BNPP are not specified related, for example, to sampling, measuring of significant nuclides (to be defined by IRWA), evaluation of results, and scaling factor determination.
- BNPP and IRWA do not have a clear concept, programme, and infrastructure for introducing a comprehensive waste characterisation program at the BNPP (using scaling factor methodology).
- Further work is needed for the application of WAC and methodology of their demonstration (control and checking of compliance).
- Closer technical interaction between BNPP and IRWA should be carried out, especially in topics related to waste characterization, WAC, and waste takeover.
- BNPP has not provided all design specifications of waste packages for solid and solidified waste to the WAC development team consisting of representatives of IRWA and BNPP.
- Agreement on methodology and treatment of non-conformities between BNPP, IRWA has not been reached.

6.7 Lithuania

SNF is considered as RW in Lithuania. All RWM facilities are considered as 'nuclear facilities'. There is no operating RW repository; the repository for VLLW is constructed and waiting permission for operation, a near surface facility for LILW is under construction.

In general, WAC shall be developed by waste storage and repository operators. The operators shall control the process of production of waste packages. However, the main RW producer, the Ignalina NPP, is also the operator of all waste storages and repositories after the merger with the Lithuanian RWM Organisation (RATA). Normative documents do not take fully into account the merger of the main waste producer with operator of waste facilities.

In accordance with Lithuanian law, the nuclear regulator, VATESI, deals only with matters relating to nuclear and radiological safety; other bodies are responsible for regulating non-radiological safety matters. Interfaces between radiological and non-radiological safety aspects are managed through bilateral arrangements between these regulators. Thus, VATESI is invited to comment on NPP reviews and assessments completed by other regulators and vice-versa. WAC are approved by VATESI in coordination with the Ministry of Environment and the Ministry of Health. VATESI in coordination with the Ministry of Health establishes exemption limits. Construction of a waste management facility has to be approved and surveillance of such a facility can be terminated by the Government of Lithuania after the application of the Ministry of Energy. The application has to be coordinated with VATESI.

6.8 The Netherlands

The national policy is to store all waste until the solution for its permanent disposal is found (i.e., until 2130). COVRA is able to carry out all waste management activities, including transport, except for spent fuel reprocessing. Generic waste acceptance criteria have existed since the start of operation of processing facilities and storage buildings. Generally, they are related to long-term stability, mechanical strength (stacking) and radiological criteria.

WAC for processing facilities are reviewed every year, and changes introduced when deemed necessary. The generic WAC for storage are not reviewed.

Mostly, the reason to adjust WAC is that COVRA has encountered issues with waste types that can be avoided by adjustments. Also, changing waste types (e.g., replacing glass with plastic) calls for changes in waste acceptance. Finally, changing legislation has also impacted on the WAC specification.

6.9 Romania

Waste without a management route

There are several existing waste streams lacking a management route, namely:

- Organic RW generated during Cernavoda NPP operations that do not meet WAC for incineration by a foreign operator;
- Aluminium waste and irradiated graphite generated by VVR-S reactor decommissioning;
- Disused sealed radioactive sources that are not in compliance with WAC for disposal in Baita Bihor (repository for institutional waste);
- Aluminium and beryllium waste, irradiated graphite – from future TRIGA research reactor decommissioning;
- Metallic components from the active zone of CANDU units (zirconium alloys);
- Spent ion exchange resins generated from Cernavoda NPP operations (SIER).
    - Main physical characteristics: resin beads in water;
    - Main chemical characteristics: mixture of a strong acid cation-exchange resins and strong base anion-exchange resin;
    - Radioactivity level and main radionuclides: no radiological characterisation has been carried out on the stored SIER;
    - Volume: yearly, around 6.65 m^3 of SIERs are generated from the purification systems of Cernavoda Units 1 and 2: 4.22 m^3 – fuel-contact and 2.43 m^3 non-fuel contact

Challenging issues:

- Spent ion exchange resins generated from Cernavoda NPP operations – are considered challenging waste due to their high C-14 content;
- Treatment/conditioning technology is not selected yet;
- No disposal facility is available for the RW generated from the Cernavoda NPP
- Irradiated graphite, aluminium, beryllium waste – no available technology for treatment/conditioning;
- Metallic components from NPP decommissioning – contaminated with long-lived RN; no available disposal facility.

Uncertainties associated with the waste streams:

For the spent ion exchange resins: based on available data generated by the operations of the CANDU units, only fuel contact resins (resins generated from the systems that are not coming in contact with the fuel) would meet the WAC for near surface disposal; the non-fuel contact resins (generated mainly from moderator purification system), due to the theoretically high C-14 inventory shall be disposed of in a future geological disposal facility, together with other LILW-LL. However, during long-term storage, degradation processes (chemical, radiolytic or microbiologic) could have an impact on the retained C-14. A sampling and characterisation program is going to be initiated in order to get real data regarding radionuclide inventory in the SIERs stored on Cernavoda site.

For irradiated graphite, Cl-36 activity estimated by ORIGEN simulations exceeds the WAC for the future near surface disposal facility. Measurement of the real Cl-36 content would clarify the disposal route for the irradiated graphite.

6.10 The Republic of South Africa

There is large amount of legacy waste either disposed of or stored which needs corrective actions. Adequate solutions have not been selected yet.

6.11 UK

The following points are particularly notable in the context of waste acceptance systems and related activities in the UK.

The UK waste classification approach does not distinguish between wastes containing predominantly short-lived and long-lived radionuclides – wastes are classified according to the type and quantity of radioactivity they contain and how much heat is produced. 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.

WAC are in place for the disposal of VLLW and LLW. Packaged VLLW and LLW is generally not stored for extended periods prior to disposal. There are currently no final WAC for the disposal of HLW, since a disposal route is not yet available. In the meantime, the UK has developed and applied an extensive system of generic 'WAC', which is integral to its national approach to radioactive waste management for waste destined for geological disposal. Their application enables waste conditioning (including packaging) to progress despite the relatively long lead times for siting, developing, implementing, and licensing a GDF.

RWM produces packaging specifications and associated guidance as a means of providing a baseline against which the suitability of plans to package waste for geological disposal can be assessed (collectively referred to as the Waste Package Specification and Guidance Documents, WPSGD). These are generic in the sense that they are not specific to a particular disposal facility or site. They make no assumptions regarding the geographical location of the GDF, the geological environment in which it will be constructed or the specific geological disposal concept which could be adopted. They are defined as a precursor to facility specific WAC and may also be regarded as preliminary WAC for the GDF.

Proposals by waste producers for conditioning and packaging HAW are assessed against these generic waste package specifications through several iterations and require endorsement by RWM before operations can proceed.

7 COLLABORATION WITH EXTERNAL PROJECTS

Since waste acceptance is the subject of several other ongoing and recently completed projects, run by the EC and other international organisations, links and connections to these projects have been established in order to avoid duplication and overlapping activities. With this in mind, two webinars were jointly organised by PREDIS in collaboration with the ROUTES work package of the European Joint Programme on Radioactive Waste Management (EURAD) and the ERDO working group. In addition, PREDIS representatives took part in a ROUTES workshop regarding WAC in June 2021. Notable outputs from these initiatives are summarised in this section.

7.1 Waste Acceptance Criteria Webinar 1: Information and Resources

The first technical webinar was held on April 21, 2021. More than 200 participants registered to attend the webinar from 37 countries including some from outside Europe. A total of 177 people joined the webinar over its duration.

This webinar aimed at providing information on existing projects and institutional activities regarding WAC. The programme consisted of presentations delivered by invited speakers representing these projects. The presentations as well as webinar outcomes are available on the PREDIS website (https://predis-h2020.eu/wac1-webinar-21-4-2021/).

Information on Task 2.3 of the **PREDIS** project on waste acceptance systems and an overview and update of **EURAD-ROUTES** Task 4 "Identification of WAC used in EU Member-States for different disposal alternatives in order to inform development of WAC in countries without WAC/facilities" were provided. With regard to EURAD-ROUTES Task 4, the general objectives are to provide an up-to-date overview in Member-States on the use of WAC at different stages in the waste lifecycle offer a structured approach to support decision-taking of "no regret" waste management measures, and to identify R&D needs and opportunities for collaboration between Member-States. Memorandum No. 1 from Subtask 4.1 on the current use of WAC is publicly available (www.ejp-eurad.eu/implementation/waste-management-routes-europe-cradle-grave-routes).

The **CHANCE** project on characterisation of conditioned radioactive waste aimed, amongst other elements, at the establishment at the European level of a comprehensive understanding of current conditioned radioactive waste characterization and quality control schemes across the variety of different national radioactive waste management programmes. It was found that basic assumptions for safety studies or identification of parameters evaluated through WAC could be harmonised, but that specific safety relevant parameter values could not.

A presentation about the **THERAMIN** project discussed using generic criteria for evaluating the disposability of thermally treated wastes. A set of generic disposability criteria was proposed, and it was concluded that it could be used to evaluate any form of waste product, from any thermal treatment, for disposal in any type of facility.

The goal of the **MICADO** project is to deliver a platform for non-destructive radiological analysis capable of defining the characterization procedure for the supplied waste package, determining the best measurement geometry and waste category and providing a complete integrated waste management solution for the full traceability of the waste.

The efforts of the **ERDO-LWC** (Legacy Waste Characterization) working group focus on the investigation of possibilities for sharing waste management facilities/knowledge/best practices regarding legacy waste, including the identification of a minimum set of WAC (physical-chemical-radiological) to be respected by legacy VLLW-LLW or ILW packages. The ultimate goal of the ERDO working group is enabling the establishment of one or more shared multinational waste management solutions.

OECD-NEA activities on WAC are being performed within the Integration Group for the Safety Case (IGSC) Expert Group on Operational Safety (EGOS). At present, a draft study report on WAC development is under review.

In the **IAEA** presentation WAC were described as the link between radioactive waste management operations as well as between responsible parties (waste generators, waste processors, waste storage operators and waste disposal operators). WAC also establish characterization objectives and underpin and inform sampling and characterization plans. Establishing adequate waste inventories (particularly for legacy wastes), characterization and sampling, safety case development, interdependencies between RWM steps, the absence of operating disposal facilities, waste form performance and information/knowledge management were highlighted as remaining WAC-related challenges.

Following the formal presentation sessions, a set of small group discussions were held. The aim of the sessions was to gather perspectives framed around the following topics:

- Which challenges in developing or modifying waste acceptance criteria will the presented project outcomes/objectives have the most impact on? Which challenges need to be further addressed?
- Are the needs of less mature RWM programmes (e.g., those without repositories) being addressed in ongoing projects? What is missing?
- Do the available WAC guidance documents (IAEA, NEA-OECD, EC Projects) provide enough information? Can they be improved?
- Is there sufficient need and interest to advocate for developing a document comparing the different approaches in WAC against a background of the national boundary conditions?

Some key takeaways from the deliberations of the discussion sessions were as follows:

Challenges in developing or modifying WAC:

- The requirements and limitations of all steps in the waste management lifecycle need to be considered when developing WAC. Early information helps to optimise activities.
- It can be challenging to integrate new type of waste into the existing management scheme while also demonstrating that WAC are fulfilled. Generally, there is greater confidence in using established (tried and tested) approaches.
- The development and preservation of archives on the properties of known and available waste packages would be helpful.
- Harmonisation of (preliminary) WAC among countries could be useful but will depend heavily on the level of detail at which such harmonisation is to be applied as well as who (waste generator, WMO, regulator, etc) is responsible for its application. Some criteria could be applied at a high level.
- One of the challenges is the determination and development of the methodology of quantifying parameters for the important features of WAC.
- A systematic application of common criteria would help to ensure the widespread application of best practices.

Needs of less mature RWM programmes:

- Lack of clear regulations may result in indefinite storage of waste.
- Ideally, WAC would be used not only for a box-checking exercise, but also as an instrument to help design a national policy for waste management.
- Possibly, conditioning technology can be purchased along with information on the long-term performance of the product waste forms.
- Reconditioning of waste packages originally produced without WAC might be needed.
- For programs without candidate sites for final disposal, it is difficult to determine what conditioning options are suitable for long-term storage. Is storage of final waste packages the best solution when they are derived from generic WAC and not site-specific safety case information?

Highest priority activities:

- Shared approaches/solutions regarding predisposal (especially characterization) and regulatory activities are needed.
- The sharing of waste management facilities (fixed installations, modular or mobile options) should be explored.
- Considerations other than radiological WACs may apply, chemical and toxic elements may be as important to disposal. Regulations and requirements relating to hazardous / toxic waste may require a different (possibly conflicting) approach to waste management compared to those defined for radioactive waste.
- Characterization (and representative sampling) is a clear challenge to WAC development, particularly for legacy wastes.

Gaps:

- The trade-off between early conditioning and postponed conditioning should be explored.
- In many cases, there is no option to postpone conditioning (i.e., storage of raw waste is not permitted). It would be useful to know how these situations are universally handled.
- There seems to be a communication gap between the field of characterization (which is generally laboratory-oriented) and the field of WAC establishment (which is generally engineering-oriented). Maybe an explicit account of measurement uncertainties in the establishment of WAC could serve as a bridge.
- Does a new “final conditioning” step need to be introduced into predisposal waste management?

General:

- Information (from the presented projects, etc.) about waste characterization is useful.
- When using preliminary WAC in waste management, it is advisable not to be overly conservative.
- The large number of projects and activities (EC, IAEA, NEA, …) on the same subject may lead to conflicting results if high-level cross checking is not performed.

Live polling indicated that:

- Most respondents considered the absence of disposal facilities to be a main obstacle to the management of radioactive waste.
- Most respondents agreed that defining appropriate WAC and checking compliance (including characterisation) are the most challenging aspects of WAC.
- Respondents were more divided on the most appropriate course of action in the absence of disposal solutions and/or WAC; similar numbers of respondents felt that waste should be treated but not conditioned, waste should be treated and conditioned according to best practices, or waste should be treated and conditioned based on preliminary WAC. Fewer respondents considered it appropriate to store raw waste (safely) until WAC become available.

7.2 Waste Acceptance Criteria Webinar 2: needs, challenges, and opportunities

The second technical webinar was held on May 20, 2021. More than 170 participants from 30 countries registered to attend the webinar including some from outside Europe. A total of 119 people joined the webinar over its duration.

This webinar was aimed at identifying the most pressing WAC-related issues facing waste owners, generators, and management organizations as well as approaches to deal with them. The programme for this webinar consisted of two sessions of presentations by invited speakers: a session on general stakeholder perspectives and a session on end user perspectives. The presentations as well as webinar outcomes are available on the PREDIS website (https://predis-h2020.eu/wac2-webinar-20-5-2021/).

The webinar was opened by a summary of key **takeaways of Webinar 1**. Highlighted outcomes (see the previous section) included challenges in developing and/or modifying WAC, the needs of less mature RWM programmes, highest priority activities, and whether the projects presented in WAC webinar 1 were addressing identified needs.

A presentation on the **history of WAC** development emphasized that many lessons have been learned along the way. The importance of WAC and corresponding processes to overall waste management and the necessity of developing waste acceptance procedures very early in the waste management programme were stressed. Lastly it was noted that a great deal of experience is available, and it should be taken advantage of as much as possible.

EC expectations and activities in the areas of classification of radioactive waste and WAC are targeted to promoting cross border collaboration between Member States sharing technical and licensing practices on final disposal solutions and creating opportunities for the EU-wide market in these areas. A current EC study on radioactive waste classification schemes in the EU aims towards an aligned, harmonized application of an international regulatory framework in waste management and decommissioning.

Studsvik described experience from a decommissioning project regarding a radiological point of view for WAC compliance. Lessons learned were that characterization can be done conservatively, it is better to be done after strategic sorting and packing and it should be tailored to meet WAC. It was also advised that a continuously good dialogue with the regulator should be maintained.

The waste conditioning strategy used by **Orano** follows five golden rules: avoid waste at the source, maximize sorting and decontamination, reduce volumes, condition as early as possible, and initiate R&D at the right time. These tactics were demonstrated for a legacy waste consisting of a mix of graphite and magnesium.

NCSRD (Greece) discussed waste management concerns specific to Small Inventory Member States (SIMS). These concerns include insufficient characterization and conditioning, lack of disposal strategy, only generic or preliminary (or no) WAC available, waste management routes undefined especially for challenging wastes, lack of resources and long-term storage. SIMS need cost effective and readily implementable solutions, such as the use of waste packages/containers which can provide long-term storage stability, easy transport, waste retrieval and direct disposal acceptance or compatibility with overpacking. It is expected that results from EURAD ROUTES and PREDIS will be useful for SIMS.

COVRA described the waste management perspective from the Netherlands. The inventory consists of processed LILW, depleted uranium, vitrified HLW, spent research reactor fuel and other HLW. Mainly the management of LILW was discussed. It is expected that the wastes will be stored in above ground facilities for around 100 years and will ultimately all be disposed of in a single DGR. Wastes are processed through characterization, separation, volume reduction, immobilization and packaging steps. LILWs are durably packaged to be suitable for both storage and disposal as safety functions are largely comparable. However, long-lived mobile nuclides must be characterised for disposal purposes. Each waste type is stored in its own facility. COVRA is interested in exploring new processing routes through the EURAD and PREDIS projects.

SOGIN provided the waste management view from Italy. The disposal strategy involves the temporary storage of wastes on site until a National Repository is available, at which point VLLW-LLW will be subject to near surface disposal and ILW-HLW will be stored until a DGR can be accessed. At present, preliminary WAC are used to meet a set of qualification requirements and additional metrics based on waste characterization and dialogue with waste producers, preliminary repository designs, preliminary 'site independent' safety assessments and international best practices. Of particular interest is the trade-off between early and deferred conditioning using homogeneous/heterogeneous grouting and reversible packaging in high integrity containers, respectively.

SUJB (Czech Republic) gave a presentation on WAC from the regulator's perspective. The responsibilities of the licensees include the formulation of preliminary WAC and their updating to reflect the development of the storage/disposal project. Moreover, licensees shall consult the regulator for review and approval of final WAC, ensure that the waste accepted for storage/disposal conforms to WAC, ensure that each waste package consigned for storage/disposal is traceable, review the management system of organizations submitting waste and the quality of information provided, and establish procedures for dealing with non-conformances. It was noted that regulators encounter issues concerning a lack of knowledge or data on waste forms and waste packages.

Following the formal presentation sessions, a set of small group discussions were held. The aim of the sessions was to gather perspectives framed around the following topics:

- How to close the gap between characterization (or lack thereof), selecting appropriate treatment and conditioning options and WAC development?
- In the absence of WAC, what are the trade-offs between preliminary treatment and conditioning and delayed treatment and conditioning, and which balance of these factors is acceptable?

Some key takeaways from the deliberations of the discussion sessions were as follows:

Approach in the absence of disposal solutions:

- Predisposal and disposal WAC should optimally be formulated together; if disposal is unavailable, good international practices can be followed.
- Reversible packaging in high integrity containers, which are viable for long-term storage and allow for deferred conditioning or possibly direct disposal, might be an answer.
- Radioactive waste processed without disposal WAC will likely require re-characterisation followed by a decision on re-processing.
- Adoption of practices similar to the UK's Letter of Compliance process can help in formulating WAC when disposal solutions are lacking.
- Even if a disposal solution is not available, future management processes should be duly envisaged.
- Moving forward blindly can be dangerous, therefore, characterization records should be kept and duly archived, mixing of waste should be avoided, etc.
- Flexibility in waste treatment/conditioning should be directly proportional to the uncertainty of a disposal solution.

Characterization and WAC development:

- Closing the gap between characterization and treatment & conditioning and WAC development will require committed communication between all relevant actors in different organizations (waste producers, waste managers, safety authorities) as well as those within the same organization (people working in the field of characterization, waste acceptors, installation development engineers…).
- Radiological, chemical, and physical characterization should be performed on raw waste as early as possible.
- For new wastes, characterization (radiological, chemical, and physical) should be performed in each phase of the process, starting from sorting, in order to avoid the mistakes of the past.
- Do not overemphasize free release radionuclide vectors; the level of conservatism is too restrictive for disposal.
- Characterization should be aligned to the planned waste management process.
- Cross-border cooperation and otherwise sharing experience in technology implementation would support WAC specification.
- Archiving representative waste samples could allow for future WAC development.

General:

- Harmonization is essential. However, harmonization across all aspects of waste management over all inventories everywhere is neither credible nor desirable. Rather, in this context, sharing of knowledge, experience and information can be considered somewhat akin to harmonizing.
- Harmonization should be viewed as an opportunity not only for identifying best practices, etc., but also for market opening and increased transparency.
- From a practical point of view, there are two main waste categories: those acceptable to near-surface type facilities and those requiring deep(er) geologic disposal.
- Absolutely key factors in the management of radioactive waste are segregation & characterisation of raw waste.
- Predisposal technologies specify requirements on input waste streams and, therefore, on RW characterisation techniques as well.
- Shared disposal facilities remain currently illusory, but in the future, namely for SIMS and HLW/SNF, they might be inevitable.
- The PREDIS project represents an opportunity to develop new conditioning and characterization methods and techniques as well as implement and share and implement any new developments.

Live-polling indicated that:

- The biggest challenges regarding WAC are considered to be harmonization, legacy wastes, and characterization.
- Sharing of solutions and information regarding WAC was considered to be of most benefit relating to characterization, small inventories, and waste form qualification.

7.3 ROUTES Subtask 4.2 workshop

This internal ROUTES workshop was held on 14-15th June 2021. It was organised by the Subtask 4.2 team who also invited representatives of PREDIS, ERDO, OECD-NEA and the IAEA. The aim of Subtask 4.2 is 'Sharing experience on waste management with/without WAC available'.

The workshop consisted of an introductory session, four 'Case studies', and three 'Cross-cutting topics': their scope was refined through planning discussions with Subtask 4.2 partners. In the opening session a brief summary of the webinars described above (Sections 7.1 and 7.2) was delivered.

A central theme of the Case studies was the dilemma of waste conditioning: when to implement it in the absence of an established disposal route. For a waste conditioning operator, it is difficult to establish a waste management scheme without WAC or with only generic/preliminary WAC, while the challenge for a disposal facility operator is to define WAC before safety analyses for the disposal facility are completed.

The Case studies included the following topics:

- Bituminization of evaporated concentrate at the Rivne NPP in Ukraine: An example of conditioning waste without disposal WAC being available.
- Cement solidification of sludges from the liquid waste evaporator in Greece: An example of conditioning prior to availability of a disposal route.
- Storage and processing of wastes at COVRA's facilities in The Netherlands: An example of conditioning waste prior to availability of a geological repository.
- Graphite management in Spain: An example of treating waste in order to establish a disposal route.

Cross cutting topics dealt with the following issues:

- Generic WAC and the UK Disposability Assessment Process.
  Interpretations of what 'generic WAC' constitute vary considerably – discussion to explore what aspects would be of most value.
- The role of stakeholders in the development and application of WAC.
  A link between safety assessment and WAC derivation, other factors influencing the scope of defined WAC, and the role of checking compliance with WAC in providing reassurance to civil society.
- Managing the potential for non-compliances to arise as WAC are iterated.
  What happens if more restrictive limits on waste acceptance are imposed based on e.g., development of the safety assessment for a planned disposal facility?

Outcomes of the workshop will be used as a basis for ROUTES Task 4 conclusions & recommendations.

8 SUMMARY AND CONCLUSIONS

Various stages of waste management programmes are reflected in the compiled national analyses. Not all countries are experienced in the practical management of WAC and their applications, but in principle, most of them have established a system that would allow for performing safe collection, characterisation, processing, and storage activities.

A framework of legislation and assigned responsibilities is available in all responding countries. Typically, operated facilities (storage, treatment, and disposal) are managed by state organizations and the processes are controlled by regulatory bodies. However, exceptions exist: private companies are in some cases responsible for managing the facilities as well.

Disposal facilities are in operation in several countries with fully functional waste acceptance systems. Those planning or constructing a repository have typically formulated generic or preliminary WAC, but for other national programmes (particularly SIMS) WAC determination remains a challenge.

WAC are usually approved in the frame of the licensing process of a repository, for predisposal activities acceptance criteria are formulated mostly as technological requirements of treatment and conditioning procedures.

Although safety assessment is widely considered as a condition or precursor for the formulation of certain WAC, the actual relation of WAC to the safety assessment of storage/disposal facilities (i.e., the method for their derivation) has not often been clearly identified. The relationship should be specified for generic criteria, if relevant, and for site specific criteria, if possible. Simple examples of using existing procedures (e.g., those specified in national documents and/or IAEA recommendations) will be helpful and could be demonstrated during the project implementation.

All countries have applied the IAEA's 'Regulations for the Safe Transport of Radioactive Material' SSR-6, which clearly defines measures assuring safety: it highlights dose rate and surface contamination as major radiation criteria. However, the long-term safety of RWM facilities depends on a broad scale of radionuclides, most of which are difficult to measure (alpha, long lived beta). Thus, proper use of activity measuring and detection techniques is a key challenge regarding WAC.

The extent of inputs from national analyses relating to the three main topics to be covered in the rest of PREDIS Task 2.3, as identified in Section 1, i.e., measuring techniques (D2.5), waste form qualification (D2.6), and generic WAC (D2.7), is somewhat varied. Nevertheless, the implementation team believes that it is sufficient for achieving the goals of the project. However, this would require some additional investigations and the utilisation of personal experience of the involved expert team for the balanced presentation of the project results.

USED ABBREVIATIONS

ASR – alkali-silica reaction
CW – conditioned waste
DEF – delayed ettringite formation
DSRS – disused sealed radioactive sources
DTM – difficult-to-measure (isotopes)
GDF – geological disposal facility
G-WAC – generic waste acceptance criteria
HAW – higher activity waste
HLW – high level waste
ILW – intermediate level waste
LLW – low level waste
LoC – Letter of Compliance
NCW – non-conditioned waste
NPP – nuclear power plant
NV – nuclear vectors
P-WAC – preliminary waste acceptance criteria
RCA – radio-chemical analysis
RN – radionuclide
RW – radioactive waste
RWM – radioactive waste management
SIER – spent ion-exchange resin
SIMS – Small Inventory Member State
SNF – spent nuclear fuel
TRU – transuranic waste
VLLW – very low level waste
WAC – waste acceptance criteria
WAS – waste acceptance system
WFQ – waste form qualification
WPT – waste package type
WTD – waste type description