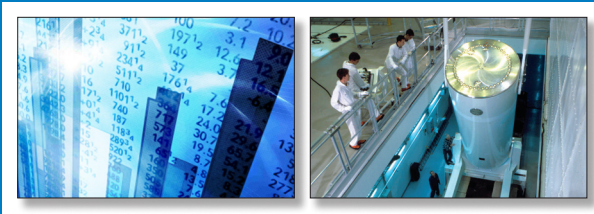


# National Inventories and Management Strategies for Spent Nuclear Fuel and Radioactive Waste

Methodology for Common  
Presentation of Data





Radioactive Waste Management

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NUCLEAR ENERGY AGENCY  
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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## Foreword

The OECD Nuclear Energy Agency (NEA) Expert Group on Waste Inventorying and Reporting Methodology (EGIRM) brings together senior representatives of national organisations with a broad knowledge of radioactive waste and spent nuclear fuel management issues resulting from their work as implementers, regulators and research and development experts or policymakers. The expert group was established by the NEA Radioactive Waste Management Committee (RWMC) in 2014 to develop a methodology that would ensure consistency of national radioactive waste inventory data presented in a common scheme. The need to develop such a methodology arose in the context of a joint initiative of three agencies – the NEA, the International Atomic Energy Agency (IAEA) and the European Commission (EC) – entitled the “Status and Trends Project on Spent Fuel and Radioactive Waste”.

The EGIRM was mandated to review the radioactive waste and spent fuel management strategies of NEA member countries with the goal of developing a common presenting format for national inventory data related to radioactive waste and spent fuel management strategies that have been established in member countries. The expert group was thus tasked with developing a methodology to support the Status and Trends Project, which is planning to publish a global spent fuel and radioactive waste inventory. This report provides a presenting scheme and a methodology for spent nuclear fuel and for waste arising from reprocessing. The extension of the methodology and presenting scheme to other types of radioactive waste and corresponding management strategies is envisaged in a second phase.

## **Acknowledgements**

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## 1. Objectives

The NEA Expert Group on Waste Inventorying and Reporting Methodology (EGIRM) was established following a decision of the Radioactive Waste Management Committee (RWMC) at the 47<sup>th</sup> meeting in March 2014. In 2013, the “Status and Trends Project on Spent Fuel and Radioactive Waste” was initiated as a joint activity of three agencies – the Nuclear Energy Agency (NEA), the International Atomic Energy Agency (IAEA) and the European Commission (EC). The first meeting of the co-ordination group was held in January 2014.

The Status and Trends Project set out to establish an instrument that would provide a better understanding of the global picture of spent fuel (SF) and radioactive waste (RW) management, and the main contribution of the NEA would be to create a methodology that would help provide this understanding. The primary objectives specified in the mandate for this expert group were set out as follows:

- Develop a methodology to ensure consistency of national RW inventory data when it is included in a common presenting scheme (this scheme will be used only to compare and combine RW inventory data).
- Support NEA members in preparing their national report for the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (IAEA, 1997), as well as the European Directive 2011/70 (EU, 2011), with the above-mentioned method being used as a tool for the comparison and compilation of data.
- Propose the above-mentioned method to be used as a tool for presenting SF/RW data when preparing publications in the context of the joint “Status and Trends” project.



## 2. Background

The International Atomic Energy Agency (IAEA) published a safety guide on the classification of radioactive waste in 1994 (SS 111-G-1.1) to guide member states in developing their waste classification. In 2008, the SS 111-G-1.1 was revised and a new safety guide, the GSG-1 (IAEA, 2009), was issued. The GSG-1 sets out a general waste scheme for classifying radioactive waste primarily based on considerations of long-term safety, i.e. on the appropriate disposal method. To collect or disseminate radioactive waste management information, the IAEA developed a Net Enabled Waste Management Database (NEWMDB) for member countries to report their radioactive waste management data, including inventories on a regular basis. To input the radioactive waste data into the NEWMDB, the IAEA proposed a “Waste Classification Matrix” and method to translate the radioactive waste inventories data from the current national radioactive waste classes into IAEA radioactive waste classes. Then, in 2011, the European Commission issued Directive 2011/70 (EU, 2011), which also requires all member countries to have a national radioactive waste classification scheme. Most NEA member countries have now established their radioactive waste classification schemes mainly according to their waste management programmes and their disposal strategies defined for different waste classes. While many of these schemes were developed using the IAEA’s waste classification (i.e. GSG-1, SS 111-G-1.1) as a reference, only a few member countries have fully adopted the IAEA’s scheme in their most recent waste classification schemes. The provision of long-term safety of radioactive waste may be very different among member countries as it depends on various parameters which are often unique to each country. These differences may lead to significant uncertainties when comparing inventories among countries, particularly during the translation of the national inventory data into the IAEA waste classes.

There is general consensus on the need to develop a method to transpose as best possible the national radioactive waste (RW) classifications to a common RW presenting scheme in which inventory data of countries can be compared (e.g. a method that would focus on the technical aspects of the disposal stages for inventory comparison). Compilation (when necessary) of data will also allow future arisings to be analysed and repository capacities to be planned. It is perhaps worthwhile pointing out that such a method would have no influence on the countries’ existing RW scheme, but would be instrumental simply in comparing and understanding the different RW management practices.

National RW classification systems are applied for the planning and organisation of RW management activities and for the establishment of a unified terminology when different RW management actors interact.

The classification of RW could be used in process of resolving the following issues:

At the conceptual level:

- definition of the RW management strategy;
- planning of the methods for RW processing, storage and disposal;
- development of requirements to define methods of RW management (collecting, processing, storage and disposal).

At the level of RW management activities (organisation):

- definition of technological operations for the collecting, processing, storage and disposal of a given category of RW;
- definition of the potential dangers of the given RW category;
- systematisation of the RW inventorying process.

In developing records for and control of RW, information exchange takes place in the framework of a unified terminology for the RW management discussion between the regulator, the implementer and other stakeholders on the national and international levels.

Other factors also being considered for the analysis of approaches to RW classification development are:

- waste qualification as RW, establishing of clearance criteria;
- establishing the RW categories (groups);
- establishing numerical values of the RW characteristics (specific activity, total activity, dose rate, surface contamination) for different RW categories and the principle for establishing them, where they are important in making decisions on RW infrastructure;
- inter-relation of the RW classifications and the RW management strategy.

The RW classification system (which defines RW categories), the general management strategy, as well as general requirements to methods of the RW management, serve only the most common issues of safety and organisation of inventorying and control of RW.

Establishment of permitted values of RW characteristics is linked to a facility-specific safety case or licence requirement and depends on the given step or activity in RW management (e.g. transportation, processing, storage, disposal), the technological process or facility, and its setting (e.g. location, environmental characteristics, geological characteristics).

It is evident that RW classification and the qualitative and quantitative criteria significantly depend on the accepted short-term and long-term strategy of RW management in the country and on their nuclear infrastructure and regulatory practices.

In general, two approaches to RW classification exist:

- The first approach is based on the division of RW according to its specific activity level and dose rate of  $\gamma$ -emission (e.g. at a distance of 0.1 metre from the surface) without regard to the disposal route. This approach is mainly based on short-term operational safety issues (e.g. operator radiation protection). This type of approach was accepted and implemented in Russia, some former Soviet Union republics and other countries (usually in Eastern Europe). According to the level of specific activity, RW is often divided into high-level waste (HLW), intermediate-level waste (ILW) and low-level waste (LLW) categories. Wherein the boundaries for  $\gamma$ ,  $\beta$ -emitters are 10 times higher than for  $\alpha$ -emitters and 100 times higher than for transuranic nuclides.
- The second approach to RW classification is linked to long-term safety, and by implication to disposal routes, and takes into account the specific radionuclides, half-life, heat emission and total activity of RW packages. This approach is currently implemented in international normative documents (e.g. GSG-1 [IAEA, 2009], EC Directive 2011/70/EURATOM) and has been adopted in practice in some European countries, in Japan and in the United States, which have or plan to have different disposal routes for different types of RW. This second approach is less easily applicable in countries that do not make any distinction in disposal routes (e.g. all wastes are destined to a single deep disposal facility).

Listed below are some of the important factors that have influenced the development of national RW classification schemes:

- The main mass (over 96%) of solid RW from the nuclear fuel cycle is uranium mining RW. This can be characterised as very low-level waste (VLLW), consisting of naturally-occurring radioactive material (NORM) with a specific activity that does not normally exceed 100 KBq/kg. Considerable RW mass is stored in the tailings of mining enterprises not conditioned and not isolated from the environment. Some countries distinguish such waste as a separate category (uranium mining and milling waste – UMM), while other countries do not consider this to be RW at all.
- Currently, Russia and the United States have a considerable amount of liquid RW at various locations (in tanks, pools and open air ponds), mainly resulting from historic activities. In addition, Russia applies the technology of deep injection of liquid RW in three deep underground facilities. Thus, there is a need for Russia to have a specific RW class for injected RW.
- Due to ageing nuclear fleets and related fuel cycle facilities, an increase in decommissioning activities is anticipated in many countries in the near future. This will lead to growth in the volume of RW. The main waste after decommissioning is surface-contaminated materials and building rubble that could be cleared from regulatory control after decontamination, reused or disposed of as VLLW. Such waste normally does not require as stringent technical measures (as for the LLW and higher) during handling, treatment and disposal due to its very low activity. In addition to very low activity, the

large volumes and/or component sizes may make traditional packaging (e.g. 200 L drums) as well as monitoring for clearance impractical.

- Nuclear power plants (NPPs) and other large nuclear facilities (e.g. fuel cycle facilities, research centres) often have at their sites all RW management stages: collection, processing, temporary and long-term storage. Hence, a considerable amount of different RW is often housed at these sites for interim or long-term storage.
- Disused sealed radioactive sources (DSRS) management practices have some peculiarity, including for disposal, and can be regulated by separate rules. Some countries include sealed sources as a separate category, while others include them in their general RW categories.
- The available waste management infrastructure (e.g. disposal routes, processing facilities) and societal preferences have an influence on how RW is categorised. For example, in Germany and Switzerland, all RW is destined for deep geological disposal. In these cases, there is less of a need to distinguish between long-lived and short-lived waste and between LLW and ILW, since they are destined for the same disposal facility. Such an approach can also simplify the RW management system, by not requiring characterisation and categorisation of each individual waste package.

### 3. Requirements for the methodology

The general objectives of the expert group are defined in the mandate of the EGIRM, which provides an understanding of what kind of methodology should be developed. However, more detailed and concrete requirements for the methodology are needed to provide clear technical limits within which the methodology should be developed, and at the same time to establish a level of a quality for the data presentation. Some requirements were formulated based on the previous review performed by the RWMC. Others could be defined after an additional specific review of national programmes. Thus, the initial stage of the methodology development was a study of the background of national RW classification schemes in NEA member countries, definition of the most important factors influencing the methodology concept, and the determination of the form and method of implementation. Goals addressed by the national RW classifications, criteria used for defining RW classes, numerical values of boundaries between RW classes, national management strategies and disposal routes were analysed by the EGIRM. During the analysis of the current situation in NEA countries, the main requirements were specified for the development of the methodology, and include:

- The methodology should not replace the GSG-1 (IAEA, 2009) or provide any new radioactive waste (RW) classification scheme. It should only be an instrument for presenting, comparison and compilation (if necessary) of data from different countries and should work in conjunction with the GSG-1 and national classification schemes.
- The methodology should be a technically-oriented tool based on the technical aspects of suitable final disposal routes.
- Taking into account a variety of strategies of management for similar RW classes in different countries, the methodology should focus on decisions and strategies accepted in the countries regarding each RW class. Spent fuel (SF) management should also be covered, regardless of whether it is considered a waste or not in the country.
- The methodology should define RW groups (with subgroups where necessary) in such a way as to provide a clear and unambiguous understanding of what RW is included in each group and what disposal strategy is recommended for the group.
- The number of such groups should be as limited as reasonably possible.

- The methodology should first focus on SF and high-level waste (HLW) (RW after reprocessing of the SF). Further RW classes can be added subsequently.
- The methodology should be simple, applicable to all existing national RW classification schemes, for countries with different RW management needs and cover all kinds of radioactive materials considered RW in any country (e.g. “legacy waste”, problematic RW [polyvinyl, graphite, sodium, asbestos], surface contaminated waste, different kinds of naturally occurring radioactive material [NORM], sealed sources). It should not require significant efforts from country representatives for application (e.g. complicated recalculations or assessments) and should be intuitive and user-friendly.
- The methodology should use universal units for all RW classes and consider comparable forms of RW (e.g. solid [when possible], conditioned [when applied], ready for disposal). It should operate with clear and easy-to-understand definitions, should cover international SF/RW management activities (reprocessing, treatment, storage, etc.) and address the requirements of international binding documents (Joint Conventions, EC 2011/70 Directive).

The following definitions were therefore developed for the methodology:

- The “servicer” is the country where the SF is to be reprocessed or where any other service is to be provided according to the international agreement.
- The “user” is the country that used the nuclear fuel (i.e. generates the spent fuel) and then sent it to “servicer” according to international agreements for reprocessing (or any other specific service).
- “Nuclear power plants’ spent fuel” (NPP’s SF) is fuel that was used in a reactor built and operated for the commercial production of electricity, extracted from the reactors and inventoried in the national inventory. RW formed after reprocessing of such SF is also included in the methodology objectives for nuclear power plants.
- “Other reactors’ spent fuel” is fuel that was used in reactors built and operated for purposes other than commercial electricity production (such as science, medicine, transport, isotope production, etc.), extracted from the reactors and inventoried in the national inventory. RW formed after reprocessing of such SF is also included in the group “other reactors”.



## 4. International approaches

Work on the methodology development focused first on the collection and analysis of information regarding existing approaches on how to harmonise the presentation of national radioactive waste (RW) inventories and existing types of disposal facilities. It was necessary to avoid any duplication of principles and content of the methodology with other methods/approaches and to assess the applicability of existing approaches for the purposes of the NEA Expert Group on Waste Inventorying and Reporting Methodology (EGIRM).

### 4.1. International Atomic Energy Agency (IAEA) documents

The following IAEA documents were reviewed and analysed:

- *Classification of Radioactive Waste*, GSG-1 (IAEA, 2009);
- *Classification of Radioactive Waste*, SS 111-G-1.1 (IAEA, 1994);
- “Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management” (IAEA, 1997);
- “Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. Guidelines regarding the Form and Structure of National Reports” (IAEA, 2012);
- “Guidance on Translation of Member State Waste Classes for Purposes of Reporting Waste Inventories to the Net-enabled Waste Management Data Base” (IAEA, 2010).

Before 2009, the *Classification of Radioactive Waste* (IAEA, 1994) provided a universal RW classification and guidance for RW classification application. This document defined three main classes of RW: Exempt waste (EW), low- and intermediate-level waste (LILW) (with subclasses of short-lived [LILW-SL] and long-lived [LILW-LL]), and high-level waste (HLW) along with some values of characteristics to distinguish these classes (see Table 1):

- EW – waste to be excluded from regulatory control.
- HLW – based on high heat emission and total specific activity.
- LILW-SL – waste with mainly short-lived radionuclides ( $\leq 30$  years), containing limited concentration of alpha emitters and long-lived radionuclides, negligible heat emission, etc.
- LILW-LL – waste containing long-lived radionuclides above the limit for LILW-SL, and other values of similar parameters.

This classification scheme was accepted by the European Commission (EC) for reporting. Currently, most of the numeric values for the classification criteria are still used in the actual classification schemes of many countries.

**Table 1. RW classification (Safety Series No. 111-G-1.1)**

Waste class	Typical characteristics	Disposal options
1. Exempt waste (EW)	Activity level at or below clearance levels given in No. III-G-1.5, IAEA, which are based on an annual dose to members of the public of less than 0.01 mSv	No radiological restrictions
2. Low- and intermediate-level waste (LILW)	Activity levels above clearance levels given in No. III-G-1.5, IAEA and thermal power below about 2 kW/m <sup>3</sup>	Near-surface or geological disposal facility
2.1. Short-lived waste (LILW-SL)	Restricted long-lived radionuclide concentrations (limitation of long-lived alpha emitting radionuclides to 4 000 Bq/g in individual waste packages and to an overall average of 400 Bq/g per waste package);	
2.2. Long-lived waste (LILW-LL)	Long-lived radionuclide nuclide concentrations exceeding limitations for short-lived waste	
3. High-level waste (HLW)	Thermal power above about 2 kW/m <sup>3</sup> and long-lived radionuclide concentrations exceeding limitations for short-lived waste	Geological disposal facility

In 2009, the IAEA provided a revised RW classification scheme where the classes were restructured and several new classes were introduced. The classification proposed consists of: exemption waste (EW), very short-lived waste (VSLW), very low-level waste (VLLW), low-level waste (LLW), intermediate-level waste (ILW), high-level waste (HLW), and gave the way to application of RW classification for inventorying purposes. This scheme is given in the *Classification of Radioactive Waste, GSG-1* (IAEA, 2009). Some of quantitative criteria of the classification system were removed and now the description of classes is more qualitative. This allows greater flexibility for countries to adopt site-specific boundaries between classes more suited to their infrastructure and regulatory needs. However, it provides little guidance to countries who are just establishing their programmes.

The GSG-1 gives several quantitative parameters to distinguish RW classes:

- A boundary between EW and VLLW is given in the table of values of criteria for clearance, exemption and exclusion for individual radionuclides given in “Application of the Concepts of Exclusion, Exemption and Clearance, IAEA Safety Standard Series No. RS-G-1.7”. The so-called “exemption level” (EL) is based on a value of effective dose to individuals in a year (not more 10 µSv) for artificial radionuclides and natural concentration for natural radionuclides.

- The upper boundary for VLLW (and respectively the lower one for LLW) is proposed at one or two orders of magnitude above the EL (for short-lived nuclides and limited total activity). The boundary between short-lived (SL) and long-lived (LL) is established at value of half-life time of about 30 years (i.e. Sr-90 or Cs-137).
- The upper boundary for LLW is given as 400 Bq/g average per waste package (4 000 Bq/g in individual waste packages) for LL  $\alpha$ -nuclides (example of some countries, deviations are possible) and up to tens of kBq/g for LL  $\gamma$ ,  $\beta$ -nuclides. In addition, the value 2 mSv/h of contact dose rate is given to distinguish LLW and ILW.
- The boundary between ILW and HLW is based on heat emission 2-20 kW/m<sup>3</sup> (total activity – 10<sup>4</sup>-10<sup>6</sup> TBq/m<sup>3</sup> – 10<sup>9</sup>-10<sup>11</sup> Bq/g approximately).

In comparing two IAEA schemes, the 1994 classification of LILW-SL can be considered equivalent to the GSG-1 LLW and the 1994 LILW-LL can be considered equivalent to GSG-1 ILW, since these categories in both schemes are distinguished by the amount of long-lived radionuclides present.

The GSG-1 stipulates that the existence of various different national schemes “makes communication on waste management practices difficult nationally and internationally, particularly in the context of the Joint Convention on the safety of SF management and on safety of RW management”. However, guidelines on the form and structure of national reports (IAEA, 2012) do not require or recommend providing transposed RW inventory data in national reports but only recommend to “use clearly defined waste categories when reporting inventories”. Therefore, national reports mostly do not contain RW inventory data transposed into the IAEA GSG-1 classification. Information on RW inventory usually is given in the national schemes, some of which are based on the older 1994 IAEA classification system, some based on GSG-1, but mostly on neither.

Further, it is stipulated that “the classification scheme developed in this publication is mainly based on long-term safety considerations and can be applied for all waste management activities.” (IAEA, 2009: A.6.) It is important to highlight that the objectives when developing the methodology aim to support the GSG-1 with an additional tool of RW inventory interpretation that is more technically oriented. This approach should allow for a consideration of national RW/SF management from the point of view of the real national approaches to RW/SF management. Thus, consideration of the GSG-1 provisions is undertaken from the perspective of EGIRM objectives.

“The main consideration for defining waste classes in this publication is long-term safety. Waste is classified according to the degree of containment and isolation required to ensure its safety in the long term, with consideration given to the hazard potential of different types of waste” (IAEA, 2009: A.8.).

The GSG-1 scheme was developed to cover all kinds of RW with its classification. This means that liquid (and possibly gaseous) RW can be attributed to the same classes as solid RW. It may lead to some uncertainties in the national inventories when transferred to the GSG-1 scheme. The mix of liquid and solid RW can be presented in the national inventory under the same RW class. To overcome

these uncertainties, countries should either divide this class into subclasses or recalculate the initial volume of liquid waste into processed solid forms and present the liquid waste as solid (as disposed). The conflict arises between safety aspects (IAEA standards) and presenting needs. When presenting current RW inventory, the countries should reflect the safety of their RW as well as comparability of RW volumes, but it is rather difficult to meet both of them with the one scheme.

The Joint Convention and supporting document INFCIRC/604/Rev.2 (IAEA, 2012) do not require that RW inventory data be transposed into the GSG-1 RW classification scheme.

- “Contracting Parties are encouraged to use clearly defined waste categories when reporting inventories” (IAEA, 2012: Section D).
- “This report shall also include:
  - (ii) an inventory of spent fuel that is subject to this Convention and that is being held in storage and of that which has been disposed of. This inventory shall contain a description of the material and, if available, give information on its mass and its total activity;
  - (iv) an inventory of radioactive waste that is subject to this Convention that:
    - (a) is being held in storage at radioactive waste management and nuclear fuel cycle facilities;
    - (b) has been disposed of;
    - (c) has resulted from past practices.” (IAEA, 1997: Article 32).
- “Contracting Parties are encouraged to report here on their experiences concerning transboundary movements.” (IAEA, 2012: Section I).

## 4.2. The NEWMDB practice

The “Net Enabled Waste Management Database” (NEWMDB) was developed as a tool for countries to report their RW inventories, and it allows the IAEA to compute some statistics on this data. The IAEA’s scheme is proposed in NEWMDB as an international and universal waste classification scheme and implemented in the NEWMDB for the common presentation of RW inventory data for member states (MS). To transpose a national classification into the IAEA’s NEWMDB, a methodology and guidance is given in a “technical” document entitled “Guidance on Translation of Member State Waste Classes for purposes of Reporting Waste Inventories to the Net-Enabled Waste Management Data Base” (IAEA, 2010). This methodology has several features, including:

- First, the NEWMDB does not consider EW and VSLW – an approach may be considered reasonable for the EGIRM as these RW classes can be considered conventional ones. It is more expedient to exclude them from consideration for the methodology objectives.

- Second, the NEWMDB method considers four cases of transposition of national RW classification into the IAEA scheme (GSG-1):
  - a) when national classification fully follows the IAEA’s GSG-1 (Australia, for example);
  - b) when national classification follows the IAEA’s Safety Series No. 111-G-1.1 (Czech Republic, Hungary and particularly, Norway);
  - c) when national classification is absolutely different from the IAEA cases listed above (majority of countries);
  - d) when there is no RW classification.

For case (a), no transposition is required, since the classification is already in the desired format.

For case (b), guidance is provided in the form of the matrix of transposition (below) based on the application of waste acceptance criteria (WAC) (if they exist) or on an assessment of specific activities of individual radionuclides and compared with exemption levels (to distinguish VLLW and LLW).

**Table 2. Matrix of transposition**

New NEWMDB waste class	Previous NEWMDB waste class		
	LILW-SL	LILW-LL	HLW
VLLW	X%	0%	0%
LLW	(100-X)%	0%	0%
ILW	0%	100%	0%
HLW	0%	0%	100%

There is a difficulty with application of such an approach to big volumes of LILW-SL (a previous class that was already inventoried in a country) to separate the VLLW volume as it requires revision and re-evaluation of all LILW-SL volumes. In addition, some countries do not recognise VLLW as a separate class from LLW and are reluctant to artificially make the distinction when it may be contrary to their regulations.

For case (c), the application of a WAC is recommended. If there is no WAC in a country it is proposed to analyse all available information about RW, to use the table of class boundaries (see Table 3) and to assess the specific activities of nuclides. Then, on the basis of this assessment and using Table 3, it is proposed to convert national classes into GSG-1 classes.

For case (d), the direct application of GSG-1 is recommended. Similar to case (a), no further transposition is required.

- Third, the NEWMDB accepted data on different, non-comparable forms of RW (liquid and solid), although the conditioned forms were recently accepted as useful for comparison and relevant changes have been made in the NEWMDB. When data on conditioned RW forms cannot be provided, a relevant explanation is requested in relation to the given volume.

**Table 3. Supporting table to translate national RW inventory into the GSG-1 scheme**

NEWMDB waste class	Minimal disposal option <sup>(1)</sup>	Suggested <sup>(2)</sup> waste class boundary conditions for NEWMDB reporting	
		Lower limit	Upper limit
HLW	Geological repository	10 <sup>8</sup> Bq/g total activity; heat generation of 2 kW/m <sup>3</sup> <sup>(3)</sup>	
ILW	Intermediate depth repository	Long-lived alpha emitters 4 000 Bq/g (maximum single package) or 400 Bq/g average over packages <sup>(4)</sup>	10 <sup>8</sup> -10 <sup>9</sup> Bq/g total activity; heat generation of 2 kW/m <sup>3</sup>
LLW	Near-surface	~100 times the Basic Safety Standards (BSS) exemption levels. (For waste not containing alpha activity a limit of 100 Bq/g average activity may be used) <sup>(5)</sup>	Long-lived alpha emitters 4 000 Bq/g (maximum single package) or 400 Bq/g average over packages
VLLW	Landfill		100 Bq/g total activity <sup>(5)</sup>

- 1) The term “minimum disposal options” reflects the fact that except for HLW the waste can be safely disposed of in not only one repository type, but more. Minimum disposal option stands for the least conservative option.
- 2) Suggested in the event that specific or similar limits are not available in the member state.
- 3) Activity level consistent with values in illustrative example in GSG-1; heat generation consistent with superseded Safety Series 111-G-1.1.
- 4) Maximum and average activity level consistent with values in illustrative example in GSG-1 and values within superseded Safety Series 111-G-1.1.
- 5) Typical value, used for VLLW repository at Centre de l'Aube.

The main shortcoming of this approach is the necessity for the NEWMDB country co-ordinator to review all RW inventory data and to assess the values and attributes of the RW. It is more or less achievable in the case of centralised management of RW for countries with small to mid-sized nuclear programmes or if very detailed computerised waste inventory records exist. However, if RW in a country is managed in different places, in different packages, and the country possesses a large amount of RW (for example, nuclear legacy) and/or the required level of detail is not contained in the historical records, the application of such a methodology requires serious efforts for the RW inventory transposition. It may be demonstrated on examples of countries which recently implemented new RW classifications and revised their inventories (in other words, transposed their old RW classes into new ones – e.g. Russia). However, often an exact boundary between adjacent classes (e.g. VLLW and LLW or LLW and ILW) is not significant from an overall data management perspective when aggregating data from different countries. The total amount of waste remains the same and can be safely managed under the regulations and infrastructure available in a country. The difference is in how it is allocated between the classes for international reporting purposes. In all cases, this allocation will be an approximation at best due to varying differences in numerical limits between countries.

### 4.3. The EC approach

Requirements for the form and content of national reports in the frame of the Council Directive 2011/70/EURATOM (and supporting instruction) are that “The inventory of RW should be reported according to the RW classification system presented in Appendix 2 (fully matches to GSG-1). The classification system used in the national programmes should not be used for the purposes of reporting under Article 14 of the Waste Directive, if different from the system specified in Appendix 2” (ENSREG, 2014).

Appendix 2 of the ENSREG report “Final Guidelines for MS Reports to the Waste Directive” (ENSREG, 2014), gives the RW classification and a methodology for transposing previous international classifications (equivalent EC Recommendation 1999 categories – the same as SS 111-G-1.1 [IAEA, 1994]) into the new classification scheme (GSG-1). Table 4 provides the transposition of national RW inventory presented in terms of SS 111-G-1.1 into the IAEA’s GSG-1 RW classification.

**Table 4. Matrix for transfer inventory into GSG-1**

Radioactive waste categories <sup>1</sup>	IAEA description <sup>1</sup>	Origin (examples)	Long-term management (activities and facilities)	Equivalent EC recommendation 1999 categories
Very low-level waste (VLLW)	Waste that does not necessarily meet the criteria of EW, but that does not need the high level of containment and isolation and, therefore, is suitable for disposal in near-surface landfill-type facilities with limited regulatory control. Such landfill-type facilities may also contain other hazardous waste. Typical waste in this class includes soil and rubble with low levels of activity concentrations. Concentrations of longer lived radionuclides in VLLW are generally very limited.	Mainly from decommissioning but also from other activities.	Disposal as hazardous chemical waste (with a very limited radioactive contamination) or as radioactive waste in landfill-type facilities (low engineered surface or subsurface facility).	Very low-level waste (VLLW)
Low-level waste (LLW)	Waste that is above clearance levels, but with limited amounts of long-lived radionuclides. Such waste requires robust isolation and containment for periods of up to a few hundred years and is suitable for disposal in engineered near-surface facilities. This class covers a very broad range of waste. LLW may include short-lived radionuclides at higher levels of activity concentration, and also long-lived radionuclides, but only at relatively low levels of activity concentrations.	Nuclear industry (operational and decommissioning waste) and other nuclear non-power activities (including disused sealed sources).	(1) Engineered surface or near-surface (a few metres below surface) disposal facilities  (2) Co-disposal with ILW (and possibly with HLW) in an engineered repository at greater depth is an alternative long-term management option (with the main requirements of the disposal system being determined by the highest waste category).	Low and intermediate short-lived waste (LILW)

**Table 4. Matrix for transfer inventory into GSG-1 (cont'd)**

Radioactive waste categories <sup>1</sup>	IAEA description <sup>1</sup>	Origin (examples)	Long-term management (activities and facilities)	Equivalent EC recommendation 1999 categories
Intermediate-level waste (ILW)	Waste that, because of its content, particularly of long-lived radionuclides, requires a greater degree of containment and isolation than that provided by near-surface disposal. ILW may contain long-lived radionuclides, in particular, alpha emitting radionuclides that will not decay to a level of activity concentration for near-surface disposal during the time for which institutional controls can be relied upon. Therefore, waste in this class requires disposal at greater depths, of the order of tens of metres to a few of hundred metres.	Nuclear industry (operational and decommissioning waste) and other non-power nuclear activities (including disused sealed sources).	Radioactive waste containing too high activities of long-lived radionuclides, excluding it from disposal at or near the surface with LLW. (1) Disposal in an engineered facility at a greater depth than in the case of (near) surface disposal is required. (2) Specially engineered and purpose-drilled boreholes can be an alternative option in specific cases (waste type and amount, e.g. disused sealed sources). (3) Co-disposal with HLW in one deep geological disposal facility is an option (with the main requirements of the disposal system being determined by the highest waste category).	Low and intermediate long-lived waste (LILW-LL)
High-level waste (HLW)	Waste with level of activity concentration high enough to generate significant quantities of heat by the radioactive decay process or waste with large amounts of long-lived radionuclides that need to be considered in the design of disposal facility for such waste. Disposal in deep, stable geological formation usually several hundred metres or more below the surface is the generally recognised option for disposal of HLW.	Vitrified waste from spent fuel reprocessing. Spent fuel considered as waste.	Deep geological disposal in engineered repository at depths of a few hundred metres or more – the heat output of the waste is a factor for facility design, operation and safety assessment.	High level waste (HLW)

1. IAEA Safety Guide GSG-1.

As this approach is totally based on the GSG-1 provisions, it is reasonable to anticipate the same points as in the case of the GSG-1 discussion (see above).

The main requirements related to EGIRM objectives for reporting of SF/RW inventory are given in the text below.



“On the basis of the Member States’ reports, the Commission shall submit to the European Parliament and the Council the following: ...  
 (b) an inventory of radioactive waste and spent fuel present in the Community’s territory and the future prospects.” (EU, 2011: Article 14)

This provision is one of the justifications for the need to have a tool for comparison and compilation of data.

The supporting guidelines (ENSREG, 2014) have no legal status for EC members, however, they give recommendations on improving the content of national reports for Directive objectives. Countries use these recommendations voluntarily. Nevertheless, it makes sense to review these provisions to get useful ideas on the common understanding of reporting principals and presenting options of the developed methodology.

“While the inventories of SF and RW are the basis of the national programmes, Article 14 of the Waste Directive requires regular reporting of the inventories.

In order for the Commission to deliver consistent information about the inventory of radioactive waste and spent fuel to the Council and European Parliament, member states are recommended to utilize a unified radioactive waste classification system in their National Reports.

It is proposed that the IAEA Classification of 2009 (IAEA Safety Guide “Classification of Radioactive Waste” GSG-1, 2009) is used as the basis for the unified system. Guidance on how to transform national classification schemes into the unified system is provided in Appendix 2.

Note: It is suggested that for the purposes of clarity that member states provide the Commission with information on how they have translated their national classification systems into the unified system. It should be noted that for the purposes of notifying the national programme, member states should use their national classification systems.” (ENSREG, 2014: 6)

Other aspects, some of which are listed below, were taken into account to specify the presenting features of the developed methodology and to provide relevant capacity for the presenting table. These include references such as:

“Therefore, it will be necessary to focus the inventory reporting on the main waste categories in direct relationship with long-term management by or towards disposal, and to clearly indicate in the inventory reporting the relationship between the main waste categories and the disposal routes.

Inventory reporting by MS should also be based on common rules such as units and reference dates, in order to obtain homogeneous and easily comparable and interpretable information”.

“In the reporting on the radioactive waste and spent fuel inventory, MS should clearly indicate for each of the main waste categories the considered, planned or operational disposal routes”.

“Member States have also national policy and management flexibility in terms of separate disposal facilities for each waste category or combined disposal facilities for more than one waste category. A MS might plan to develop one single disposal facility for all its radioactive waste. If radioactive waste from two or more waste categories is (or is planned to be) co-disposed in one disposal system, this should be indicated in the reporting either by providing a waste volume for the two or more combined categories (e.g. LLW+ILW or ILW+HLW) linked to one disposal system or by providing waste volume estimations for each of the waste categories that are or will be routed to the same disposal system.” (ENSREG, 2014: 26-27)

The recommendations to reporting on SF and RW inventory given in quotations below provide a good base for understanding the EC request on the format of reporting, and thus presenting data. The EGIRM used these recommendations in its work.

With regards to RW inventory “The following information should be provided:

- Waste volumes (m<sup>3</sup>) by category disposed of in (an) operational or closed disposal facility(y)(ies). For operational disposal facilities the existing total capacity (m<sup>3</sup>) should also be given.

Member States which have exported waste for disposal should indicate the quantities concerned (volumes in m<sup>3</sup> by category) and countries of destination, and refer to the export agreement(s).

- Waste volumes (m<sup>3</sup>) of conditioned waste by category stored in storage facilities. For unconditioned waste in storage, if possible, some indication of the final conditioned volume should be provided.

This should include waste currently stored abroad, subject to return, e.g. HLW from reprocessing.

MS holding foreign waste for return should indicate quantities and destinations (EU or non-EU countries)”. (ENSREG, 2014: 27)

While reporting the SF inventory it is requested that “The following information should be provided:

- Quantities of spent fuel disposed of (tHM, number of assemblies and type – BWR, PWR, CANDU, MOX, spent fuel from research reactor, ...);

If shipped to another MS or outside EU for disposal (or reprocessing without return of waste): quantities in tHM, number of assemblies and type, countr(y)(ies) of destination, and reference to the export agreement(s).

- Quantities of spent fuel in storage (tHM, number of assemblies and type (BWR, PWR, CANDU, MOX, spent fuel from research reactor, ...) by store type (dry cask, vault, pond) and locations (number of locations could be acceptable if this is seen as sensitive).

For spent fuel from research reactors, the quantities of fuel subject to a “return” agreement should be indicated.

MS should indicate separately the quantities and location of spent fuel stored abroad awaiting reprocessing. Correspondingly MS holding foreign fuel should indicate the quantities stored from EU and non-EU countries.” (ENSREG, 2014: 28)

Rather wide requirements for reporting the SF/RW are observed in the EC’s approach, and the need for a tool of harmonisation is clearly visible.

#### 4.4. The NEA approach

The NEA does not currently require translation of national RW inventory data into any common scheme. However, it is important to point out that RW inventories provided in national profiles and national reports are usually recalculated as final disposed volumes by the majority of NEA countries. It is one of the most important actions to make inventory data more or less comparable on an international level since, only solidified, conditioned forms of RW can be adequately compared (except in cases where liquid is the final form to be [or already] disposed of). On the other hand, it is important to recognise that this recalculation is mostly reasonable from the point of view of disposal. If a picture of the current situation in RW management (stored forms) is needed, the real volumes (existing, not recalculated) should be available.

The annual NEA publication, *Nuclear Energy Data* (or the “Brown Book”) contains official information provided by OECD member country governments on nuclear energy, including projections of total electrical and nuclear generating capacities to 2035 and short narrative country reports updating the status, trends and issues in the OECD nuclear energy programmes.

In addition, the publication contains information related to the fuel cycle including:

- SF storage capacities (tonnes of HM) with prognosis until 2035;
- SF arisings and cumulative in storage until 2035;
- SF reprocessing capacities (tHM/year) until 2035.

Information regarding the management of SF is presented in the form of summary tables. This provides some level of harmonisation. However, the “Brown Book” collects and presents information without specifying any disposal strategy and does not provide a full view of SF management in member countries. In some cases, it does not present a complete picture as some countries do not report certain types of SF inventory (e.g. SF stored in at-reactor pools). Hence, the approach of the “Brown Book” cannot fully address the objectives of the EGIRM.

Future updates of the “Brown Book” would also benefit from the consistency of the EGIRM approach.

#### **4.5. Observations in relation to EGIRM objectives**

- Most NEA countries have already established actual RW classification schemes and systems of recording, inventorying and reporting of RW inventories management issues based on these schemes. Most countries have actual disposal routes or have taken the general decisions on disposal routes for each class of RW established in their systems. The long-term safety of RW disposed of in relevant facilities is to be appropriately approved and is the responsibility of the individual member states.
- Different countries have developed their RW classification schemes focusing on different issues: safe and secure management (Canada, Sweden), the final disposal path (Czech Republic, France), specific activity and lifetime (Poland). This can lead to some uncertainties when comparing data between countries.
- It is necessary to have a method that is able to ensure consistency of national RW inventory when it is put into an international presenting scheme and to provide the opportunity to as accurately as possible compare inventory data from the point of view of disposal. The method should be a supporting tool to make an analysis of the current status or future arisings (when needed) and the relevant demand in repository capacities. It should be considered as an instrument for the given objectives, not as a new or independent RW classification scheme.
- There is an existing international approach to classifying RW based on long-term safety related to the final disposal solution – the IAEA’s GSG-1. Classification as described by the GSG-1 is accepted as a tool of harmonisation of the national RW inventories by the EC and the IAEA for the NEWMDB programme. However, analysis has shown that the GSG-1 does not provide a tool for visualisation of the overall inventory and management strategy. An additional presenting tool would be useful to support implementation of the GSG-1 scheme for presenting SF and RW inventories.
- Requirements for reporting in the framework of the Joint Convention (IAEA, 1997) do not include the necessity to apply the GSG-1 provisions and the member countries are requested to provide the RW inventory data in their national classification scheme.
- The EC in the 2011/70 Directive and supporting document recommends the provision of the national RW inventory in a unified form and the GSG-1 scheme is given as a tool for unification. At the same time, the directive encourages countries to provide information on RW amounts in direct relation to the accepted disposal route and also to demonstrate the transboundary movement of the SF and RW in accordance with international agreements.

- To use the GSG-1 RW classification in the framework of the NEWMDB, guidance on transposition (translation) of the national classification into the GSG-1 scheme is provided by the NEWMDB team. This method is not in accordance with the objectives of the EGIRM.
- For transferring national RW inventory data into the GSG-1 scheme, countries with no defined disposal routes are referred by default to the disposal strategy (route) described in IAEA documents. However, in reality, the strategy accepted in a country for a given RW class can be quite different from that in another country. Therefore, comparing the RW inventory data from different countries, it is difficult to describe the real picture of RW management in these countries. LLW can be disposed of in near-surface facilities in one country and in a deep geological repository (DGR) in another.
- It is necessary to adapt to existing conditions in the national RW classifications during the development of the methodology and provide an instrument acceptable for all users.



## 5. The state of the art in NEA countries

### 5.1. Spent fuel management in NEA countries

It is necessary to specify the scope of the methodology in relation to spent fuel (SF).

To be universal, this methodology should cover SF from different kinds of reactors (nuclear power plants [NPPs], research reactors [RR], transport reactors, etc.). It is necessary to bear in mind that NEA activities do not specifically cover any military applications, including the SF. However, provision should be made to accommodate all kinds of SF being inventoried in a country, including that of military applications when a country chooses to do so. The national inventory data of SF has largely been given in a breakdown by type of reactor and there is no particular issue to provide this data distributed in groups according to the origin of SF.

The SF management strategies can be divided into four basic categories:

- direct disposal as high-level waste (HLW) or as a specific type of radioactive waste (RW);
- processing and disposal of formed RW;
- shipment for processing in other countries (SF can be stored for a long time awaiting reprocessing);
- storage waiting for a strategy (can be long-term storage).

It should also be taken into account that the SF management strategy can change in some countries over time for different reasons and the national inventory may contain SF as well as HLW (and/or other RW) after reprocessing.

Several countries consider SF as HLW and others consider SF as a specific kind of RW. In countries with advanced nuclear programmes, it is possible that several management strategies exist for SF from different types of reactors or from different operators of reactors. For example, in a fully commercial environment, individual reactor operators may choose whether or not to reprocess their SF. In other countries with multiple types of reactors, SF from one reactor type might be reprocessed, while other types might not be. In other cases, the SF from a reactor type (e.g. light water reactor [LWR]) might be reconfigured as fresh fuel for another reactor type (e.g. pressurised heavy water reactor [PHWR]).

One question regarding inventorying and presenting is how to present SF sent for reprocessing or repatriation abroad according to an international agreement. Such SF needs to be accounted for by both the sending and the receiving country

such that it is clear who sent the fuel, who received it, and that it is not double counted. Fortunately, there are very few countries that currently accept fuel from other countries, and so it is not an arduous task to cross-check inventories.

One of the most serious challenges in comparing SF inventories is the units accepted in different countries for the accounting of SF.

The following units can be used for SF inventorying:

- tHM (tonnes of heavy metal);
- number of assemblies;
- m<sup>3</sup> (cubic metres).

In one country, different units may be used for the SF from different types of reactors (research reactor SF may be accounted in number of assemblies, but NPP SF in tHM). Previous analysis has shown that a majority of NEA countries use both ways of inventorying – account of assemblies number and account of weight (recalculated into tHM).

For a clearer understanding of the national SF inventories, it may be necessary to find a universal manner of data presentation regarding the container (disposal, storage, transport, without container – NETTO). In this case, it will be important to assess the ability of countries to provide data in a unified manner. However, when the SF weight unit is used, the volume of the container is not as important. For direct disposal of SF, the design of a repository is normally dictated by the heat load, and then by the volume. For reprocessing, the requirements are dictated by mass of fuel. In both cases, reporting by tHM is the logical choice. For interim storage, the number of storage casks or storage slots is important; hence the number of fuel assemblies is more important to the facility operator than the mass. Fuel assemblies of different types and masses may equally occupy a storage slot or cask. Another factor is that most storage systems are licensed based on heat load, which is related to mass, burn-up and decay cooling time of the fuel.

A specific item of investigation is a variety of management strategies established for the SF in countries, and the need to select common points and (if they exist) differences. For countries without an accepted SF management strategy, storage aspects should also be considered (especially long-term storage).

Table 5 presents the results of studying SF strategies accepted in NEA countries. The NEA Radioactive Waste Management Committee (RWMC) national profiles and reports were reviewed as well as Joint Convention reports and other available sources of information (WNA database, national inventories, etc.)



**Table 5. SF management in NEA countries**

Country	Types of SF	Strategy	Units (reported)	Disposal/storage facility type for SF
Australia	RR	- reprocessing abroad; - returning to supplier (US).	Weight unit; N assemblies.	Storage on-site (Lucas Heights).
Austria	RR	- returning to supplier (US).	Weight unit; N assemblies.	Not planned.
Belgium	NPP/RR	- reprocessing (earlier); - no strategy (direct disposal considered currently).	Weight unit; N assemblies.	On-site storage; Central storage (Dessel HLW); DGR – advanced concept.
Canada	NPP/RR	- direct disposal as HLW.	Weight unit; N assemblies.	Long-term dry storage at each reactor site. Common storage facility at each multi-reactor site (four to eight reactors served by single storage facility); DGR – in siting.
Czech Republic	NPP/RR	- direct disposal; - reprocessing (under consideration).	Weight unit; N assemblies.	Central storage – Dukovany; DGR – early siting.
Denmark	RR	- storage; - disposal abroad (if possible).	Weight unit.	No planned.
Finland	NPP/RR	- direct disposal.	Weight unit; N assemblies.	On-site storage; DGR – Olkiluoto (construction licence granted).
France	NPP/RR	- reprocessing.	Weight unit.	Storage on-site; Central storage (La Hague); DGR – CIGEO (underground research laboratory stage).
Germany	NPP/RR	- reprocessing (stopped in 2005); - direct disposal/ returning to supplier.	Weight unit.	Central + on-site storage (Ahaus + Gorleben); DGR – siting (restarted).
Greece	RR	- returning to supplier; - interim storage.	Weight unit; N assemblies.	No planned.
Hungary	NPP/RR	- no strategy on disposal; - long-term storage.	N assemblies.	Central storage – ISFSF; DGR – early siting.
Iceland	-	-	-	-
Ireland	-	-	-	-
Italy	NPP/RR	- reprocessing abroad (in France).	Weight unit; N assemblies.	In site and outside storages – (including Elk River U-Th SF).
Japan	NPP/RR	- reprocessing (can be revised).	Weight unit.	On-site storage; Central storage – Mitsu; DGR – siting.

**Table 5. SF management in NEA countries (cont'd)**

Country	Types of SF	Strategy	Units (reported)	Disposal/storage facility type for SF
Korea	NPP/RR	- direct disposal (can be revised, not finally decided).	Weight unit;	On-site pool storage; Central storage – planned; DGR – early siting.
Luxembourg	-	-	-	-
Mexico	NPP	- no strategy.	Weight unit;	On-site pool storage; DGR – concept in general.
Netherlands	NPP/RR	- reprocessing abroad (France); - RR – disposal as HLW.	Weight unit; N assemblies	Storage (COVRA); DGR – concept in general.
Norway	RR	- disposal; - reprocessing abroad	Weight unit;	Storage (IFE); DGR –concept in general.
Poland	RR	- returning to supplier; - no strategy for future management	Weight unit; N assemblies	DGR – siting (start).
Portugal	RR	- returning to supplier	Weight unit; N assemblies	No planned.
Russia	NPP/RR	- reprocessing; - direct disposal (possible for some types).	Weight unit; N assemblies	On-site storage dry and wet; Central storage – Mountain Mining Combine (MCC); DGR – Underground Research Laboratory designing stage.
Slovak Republic	NPP/RR	- direct disposal; - reprocessing abroad	Weight unit; N assemblies	On-site storage; Central storage; DGR – concept in general.
Slovenia	NPP	- direct disposal or; - reprocessing abroad or; - multinational approach.	N assemblies	On-site wet storage; DGR – early stage.
Spain	NPP/RR	- reprocessing up to 1983; - direct disposal.	Weight unit; N assemblies	Central storage – ATC; DGR – research.
Sweden	NPP/RR	- direct disposal.	Weight unit; N assemblies	Central storage – CLAB; DGR – Forsmark (Osthammar).
Switzerland	NPP/RR	- reprocessing; - not reprocessed SF as HLW.	Weight unit; N assemblies	On-site storage; Central storage – Zentrales Zwischenlager (ZZL); DGR – siting.
Turkey*	RR	- reprocessing (as option – TBD); - direct disposal (as option – TBD).	Weight unit;	DGR.
United Kingdom	NPP/RR	- reprocessing; - direct disposal under consideration	Weight unit;	Storage (50 years) – Sellafield; DGR – early siting.
United States	NPP/RR	- reprocessing up to 1977; - direct disposal as HLW (can be revised).	Weight unit;	On-site storage wet and dry; DGR – (Yucca Mountain), implementation is suspended.

\* Information from national presentation. DRG = deep geological repository; NPP = nuclear power plant; RR = research reactor; ISFSF = interim storage facility for spent fuel.

## 5.2. HLW management in NEA countries

It is also necessary to specify the scope of the methodology in relation to HLW.

There is a variety of accepted criteria for attributing RW to this class. In general, the following parameters could be selected as basic ones to specify the RW as HLW:

- heat emission;
- specific activity of  $\alpha$ -nuclides;
- specific activities of both  $\alpha$ - and  $\beta$ -emitters;
- combination of heat emission and specific activity.

It is widely accepted that deep geological disposal is the only acceptable route for this class of RW. The HLW in different countries should be disposed of in DGRs even if the national criteria of attribution are different.

For a clearer understanding of the HLW inventory, it is necessary to find a universal manner of presenting data in terms of the container.

The GSG-1 defines (and many countries do the same) HLW as principally the heat-emitting class, but some countries consider RW as HLW on the basis of the specific activity of all nuclides (alpha- and beta-). Therefore, the fact that HLW can have different forms should be taken into account. In terms of national classifications, not only vitrified HLW could be reported. Some countries can include, *inter alia*, containers with the parts of assemblies or some graphite elements in HLW inventory.

Nine countries in the list use heat emission as a criterion to attribute the RW to class of HLW, and seven countries use the activity concentration as a criterion.

In the framework of the Expert Group on Waste Inventorying and Reporting Methodology (EGIRM) objectives, it is difficult to provide any adequate and comparable presenting of the HLW based on technical criteria because of the wide variety of such criteria used by different countries. The only one common feature for HLW in different countries is it has to be disposed of in a deep geological repository.

**Table 6. High-level waste definition in NEA countries**

Country	Lower boundary (definition of class)	Main criteria
Australia	GSG-1	HE+AC (q)
Austria	-	-
Belgium	(SF cbi) considerable HE	HE
Canada	(SF + other wastes) HE > 2 kW/m <sup>3</sup>	HE (q)
Czech Republic	(SF cbi) HE to be taken into account	HE
Denmark	-	-
Finland	(SF) high activity inventory	AC
France	> 10 <sup>9</sup> Bq/g ( $\alpha$ + $\beta$ )	AC (q)
Germany	(SF cbi) high activity concentrations + high HE	AC+HE
Greece	-	-
Hungary	HE > 2 kW/m <sup>3</sup>	HE (q)
Iceland	-	-
Ireland	-	-
Italy	> thousands of years to decay down to hundreds of Bq/g	Period of danger
Japan	origin (after SF reprocessing)	Origin
Korea	$\geq 4\ 000$ Bq/g ( $\alpha$ ), T1/2>20 years, HE>2 kW/m <sup>3</sup>	AC ( $\alpha$ )+HE (q)
Luxembourg	-	-
Mexico	origin (after SF reprocessing + SF)	Origin
Netherlands	origin (after SF reprocessing + SF) + non-HE	Origin
Norway	- (2 classifications combined)	Complex
Poland	AC > 10 <sup>7</sup> x value (EL) for individual isotopes	AC (q)
Portugal	-	-
Russia	Solid waste: AC>10 <sup>11</sup> Bq/g (H <sup>3</sup> ); AC>10 <sup>7</sup> Bq/g( $\beta$ ); AC>10 <sup>6</sup> Bq/g( $\alpha$ ); AC>10 <sup>5</sup> Bq/g (TRU); Liquid waste: AC>10 <sup>8</sup> Bq/g (H <sup>3</sup> ); AC>10 <sup>7</sup> Bq/g( $\beta$ ); AC>10 <sup>6</sup> Bq/g( $\alpha$ ); AC>10 <sup>5</sup> Bq/g (TRU)	AC (q)
Slovak Republic	no information found	
Slovenia	no information found	
Spain	appreciable concentrations $\alpha$ ; T1/2>30 y; HE	AC ( $\alpha$ )+HE
Sweden	SF	
Switzerland	origin (after SF reprocessing + SF)	Origin
Turkey	(after SF reprocessing + SF + other with high AC)	Mix
United Kingdom	significant HE	HE
United States	after SF reprocessing + liquid RW with high AC	Mix

AC – activity concentration; cbi – can be included; EL – exemption level; HE – heat emission; LB – lower boundary (low boundary for HLW defined in GSG-1 as based on heat emission 2-20 kW/m<sup>3</sup> (total activity – 10<sup>4</sup>-10<sup>6</sup>TBq/m<sup>3</sup> – 10<sup>9</sup>-10<sup>11</sup>Bq/g approx.); (q) – quantitative; TRU – transuranic.

## 6. Disposal facilities

As the methodology should provide the presentation of the national radioactive waste (RW) inventories regarding disposal strategies, it is necessary to devise a survey on existing variants of the disposal facilities and the types of facilities used or planned to be used for the spent fuel (SF)/RW disposal. Initially, the arrangement given in the IAEA documents was studied.

### 6.1. Disposal routes according to the IAEA standards

The IAEA RW classification, GSG-1, (IAEA, 2009) gives four types of disposal routes:

- “landfill disposal – disposal in engineered surface landfill-type facilities;
- near-surface disposal – disposal in engineered facilities such as trenches, vaults or shallow boreholes, at the surface or at depths down to a few tens of metres, typically from the surface down to 30 metres. (design options may range from simple to more complex engineered facilities);
- intermediate disposal – disposal in engineered facilities at intermediate depths between a few tens of metres and several hundred metres (including existing caverns) and disposal in boreholes of small diameter;
- deep geological disposal – disposal in engineered facilities located in deep stable geological formations at depths of a few hundred metres or more.”

“The depth of disposal is only one of the factors that will influence the adequacy of a particular disposal facility; all the safety requirements for disposal as established in Ref. [SSR-5] will apply.” (IAEA, 2009)

Note that the term “intermediate depth disposal” is disappearing from recent IAEA publications and has been combined with “deep geological disposal” into a category of “geological disposal”. This eliminates the need for a clear boundary between “intermediate depths” and “deep”, since in reality, this will depend on the geological characteristics of the site and its ability to provide the required degree of isolation and containment for the specified RW (e.g. one country’s “intermediate depth” may be deeper than another country’s “deep”).

It is important to bear in mind that all of the above listed routes are proposed for disposal of solid RW.

The SSR-5 (IAEA, 2011) gives a slightly different specification of the types of disposal facilities:

- “Specific landfill disposal: disposal in a facility similar to a conventional landfill facility for industrial refuse but which may incorporate measures to cover the waste. Such a facility may be designated as a disposal facility for very low-level radioactive waste (VLLW) with low concentrations or quantities of radioactive content. Typical waste disposed of in a facility of this type may include soil and rubble arising from decommissioning activities.
- Near-surface disposal: Disposal in a facility consisting of engineered trenches or vaults constructed on the ground surface or up to a few tens of metres below ground level. Such a facility may be designated as a disposal facility for low-level radioactive waste (LLW).
- Disposal of intermediate-level waste: depending on its characteristics, intermediate-level radioactive waste (ILW) can be disposed of in different types of facility. Disposal could be by emplacement in a facility constructed in caverns, vaults or silos at least a few tens of metres below ground level and up to a few hundred metres below ground level. It could include purpose built facilities and facilities developed in or from existing mines. It could also include facilities developed by drift mining into mountainsides or hillsides, in which case the overlying cover could be more than 100 metres deep.
- Geological disposal: disposal in a facility constructed in tunnels, vaults or silos in a particular geological formation (e.g. in terms of its long-term stability and its hydrogeological properties) at least a few hundred metres below ground level. Such a facility could be designed to receive high-level radioactive waste (HLW), including spent fuel if it is to be treated as waste. However, with appropriate design, a geological disposal facility could receive all types of radioactive waste.
- Borehole disposal: disposal in a facility consisting of an array of boreholes, or a single borehole, which may be between a few tens of metres up to a few hundreds of metres deep. Such a borehole disposal facility is designed for the disposal of only relatively small volumes of waste, in particular disused sealed radioactive sources. A design option for very deep boreholes, several kilometres deep, has been examined for the disposal of solid high-level waste and spent fuel, but this option has not been adopted for a disposal facility by any state.
- Disposal of mining and mineral processing waste: disposal usually on or near the ground surface, but the manner and the large volumes in which the waste arises, its physicochemical form and its content of long-lived radionuclides of natural origin distinguish it from other radioactive waste. The waste is generally stabilised *in situ* and covered with various layers of rock and soil.”

GSG-1 as well as SSR-5 proposes a range of disposal routes limited to only facilities for solid RW. However, as it is noted above, there are some disposal methods (actual or past) that do not fit in the given facility list. Hence, some RW inventory data cannot be adequately presented in the framework of the GSG-1 scheme.

## 6.2. Disposal routes in NEA countries

Classification of disposal facilities in accordance with their depth is a disputable means of classification for the purposes of the Expert Group on Waste Inventorying and Reporting Methodology (EGIRM) as there are no clear technical criteria to distinguish between, for example, the intermediate depth repository and the deep geological repository. This can lead to some uncertainty or misunderstanding. If one country has an underground repository at a depth of 300 metres, for example, would this facility be considered an intermediate or deep geological repository?

**Table 7. Examples of the disposal routes in NEA countries**

Method of disposal	Examples of application
<p>Near-surface disposal:</p> <ul style="list-style-type: none"> <li>- above ground surface level and at ground surface level;</li> <li>- below ground surface level (at depths of tens of metres).</li> </ul>	<p>Implemented for LLW (VLLW) in many countries: Czech Republic, Finland, France, Japan, Spain, Sweden, the United Kingdom and the United States.</p> <p>Implemented in Finland and Sweden for LLW and short-lived ILW.</p>
<p>Deep geological disposal:</p> <ul style="list-style-type: none"> <li>- SF/HLW – heat emitting RW;</li> <li>- LLW, ILW – not heat emitting RW.</li> </ul>	<p>Most countries with HLW and long-lived RW have investigated deep geological disposal and it is official policy in many countries.</p> <p>The preferred site for deep geological repository has been selected in some countries (France – HLW, Russia – HLW).</p> <p>Licence granted in Finland and in-process for Sweden for SF/HLW.</p> <p>Deep geological repository site selection processes for SF/HLW (and ILW in some cases) have commenced in several countries (e.g. Canada, China, Germany, Japan, Switzerland and United Kingdom) in different stages.</p> <p>Implemented in the United States for defence-related ILW and LLW.</p> <p>Under construction in Germany for non-heat generating LLW and ILW.</p> <p>Under licensing in Canada for LLW and ILW.</p>
Direct injection (only for liquid RW)	Being operated in Russia for liquid LLW and ILW.
Sea disposal	<p>Now prohibited by International agreements.</p> <p>Applied in past in varying degree by number of countries (Belgium, France, Germany, Italy, Japan, Korea, Netherlands, Russia, Switzerland, the United Kingdom and the United States) – IAEA-TECDOC-1105.</p>

A few countries use the definition “intermediate depth disposal facility” for the ILW disposal route. This is generally done in the context of their overall system: they define the requirements for “deep geological” disposal and “near-surface” disposal, with “intermediate depth” falling between the two.

In some countries, a DGR is considered as a facility for SF/HLW/ILW disposal and, sometimes, for LLW and even for VLLW. It is necessary to take into account the fact that underground facilities are used not only for the HLW/SF, and not only for solid RW.

The review performed to specify all applied (or planned) disposal routes/facilities resulted in the following list of facilities:

- DGR – definitely considered for disposal of the SF/HLW (RW of lower levels can also be disposed of there);
- underground facilities with different depths considered for different types of RW (solid) except for SF/HLW (lower levels of RW can also be disposed of there);
- deep underground facilities for disposal of liquid LLW and ILW;
- near-surface facilities with different depths – below or on surface level – considered for disposal of different types of the RW (solid) except for the SF/HLW;
- sea dumping of the solid and liquid RW (currently banned) and other methods that disposed of RW in the sea/ocean.

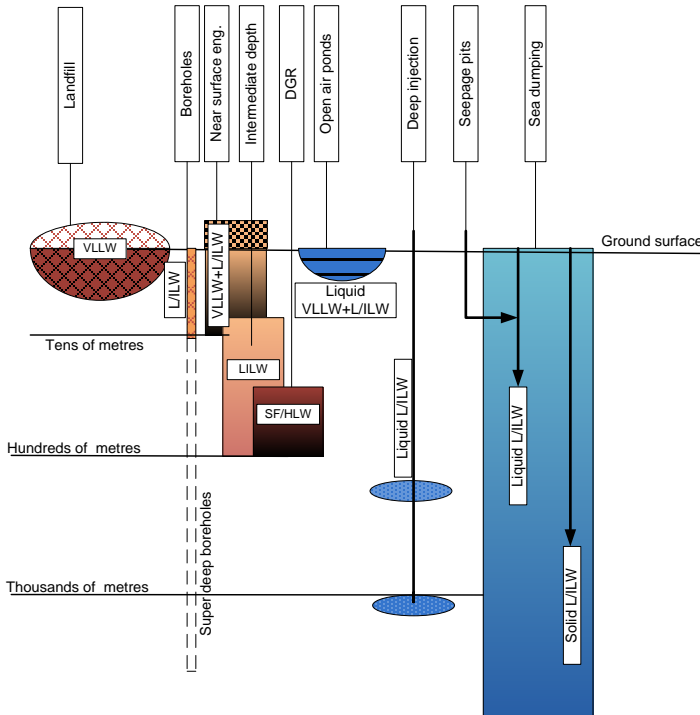
All these types of facilities are presented in Figure 1.

### **6.3. Observations in relation to the EGIRM objectives**

The study of the situation regarding the implementation (past, current or planned) of SF/RW disposal and comparison with the arrangement of the disposal facilities provided by international standards led to the following observations:

- Specific arrangement of the disposal facilities (routes) should be developed to fully meet EGIRM objectives.
- This arrangement should cover all currently existing as well as planned and previous types of disposal facilities (routes) where the SF/RW will be (or already has been) disposed of.
- The number of the facility types should be minimal.
- Each type of facility should be clearly defined.
- The definition of each type of facility should be based on a set of technical parameters. However, numerical parameters should not be used because of the large variation in the parameter values used in different NEA countries (e.g. depth).
- The list of the types of facilities should be applied in the presenting scheme as its basic element.



**Figure 1. Summary of RW/SF disposal concepts**

#### 6.4. Arrangement of disposal facilities (routes) for methodology objectives

A definition of the types of facilities (disposal routes) should be attached to the methodology. Clear definitions for each disposal route should be provided to the user to help complete the presenting table. Existing definitions (GSG-1, SSR-5) are difficult to apply to this table as they are based on the safety issues and only depth is used as a technical parameter. However, depth by itself is not a suitable criterion for definition of the disposal route in the developed methodology. A more reasonable arrangement would be all (currently, planned or past) types of facilities based on construction features.

For the SF to be reprocessed, it is proposed that the resulting RW be presented. Taking into account the possibility of a formation of not only heat emitting HLW, two subgroups are to be envisaged for the reprocessing RW. Hence, one criterion for the disposal facilities arrangement can be heat emission. As this term is understood in different ways, the EGIRM should not use any numeric values, but only indicate whether the heat emission is significant enough to be considered in the facility design. In this case, it is easy to separate an underground facility for the SF/HLW from the underground facility for other RW that has been done in this methodology. These criteria can be used as a defined set for the definition of underground facilities.

Taking into account the variety of technical solutions in concepts or designs, it does not make sense to use numerical values as a criterion to create a disposal facility classification. The EGIRM developed the simplified and widely used definitions or features as given below:

- facility position relative to ground surface: underground, near surface, etc.;
- adjoining with surface (at different stages of the repository lifetime and technical solution for such adjoining);
- application of the artificial engineered barriers in addition to the natural ones;
- limiting aspects accounted in the repository design: heat emission due to radioactivity, package, physical state, etc.

All types of underground facilities for the disposal of SF and RW after reprocessing have several common features:

- position relative to the ground surface – underground;
- adjoining with the ground surface (stage of the repository lifetime and the technical solution) – adjoined with the ground surface through tunnels, shafts, boreholes, ramps, etc. during construction and operation;

In addition, the following individual features were also developed:

- application of artificial engineered barriers in addition to the natural ones:
  - underground facility of the 1<sup>st</sup> type (UF-1) – multi-barrier principle of the highest engineering level (intensive application of artificial barriers), accounting for high concentration of radionuclides including long-lived;
  - underground facility of the 2<sup>nd</sup> type (UF-2) – multi-barrier principle of engineering level (rather wide application of the artificial barriers) sufficient for the radionuclide concentration appropriate to ILW, including long-lived;
- limiting aspects accounted in the repository design include: heat emission, package, physical state:
  - UF-1 – the SF/HLW + all others, solid, packaged (for the SF/HLW/ILW), heat emission is considered in the design;
  - UF-2 – all RW classes except for SF/HLW, solid, and some RW can be without a package, and heat emission is not considered in the design.

Similarly, the near-surface facilities can be arranged.

Near-surface facilities (NSF):

- position relative to surface – near surface below or on ground surface level;
- adjoining with the ground surface (stage of the repository lifetime and technical solution) – adjoined with the ground surface – open air during

construction and sometimes during operation (can be covered with weather shelter);

- application of artificial engineered barriers in addition to the natural ones:
  - near-surface facility of the 1<sup>st</sup> type (NSF-1) – multi-barrier principle with considerable engineering level (rather wide application of artificial barriers);
  - near-surface facility of the 2<sup>nd</sup> type (NSF-2) – multi-barrier principle with minimally reasonable engineering level (limited application of the artificial barriers);
- limiting aspects accounted in repository design include: heat emission, package, physical state:
  - NSF-1 – solid, packaged (when necessary), heat emission is not considered in the design;
  - NSF-2 – solid, package generally not required, heat emission is not considered in the design.

The NSF-2 type is currently outside the scope of the EGIRM work at this stage of the work. A summary of the proposed arrangement of disposal facilities is given in Table 8.

**Table 8. Arrangement of the disposal facilities for EGIRM objectives**

Type of facility	Features	RW classes (in terms of GSG-1) that can be disposed of	SSR-5 equivalent (1.14)
<b>UF</b>			
UF-1	<ul style="list-style-type: none"> <li>- no direct, open connection with surface during construction or operation stage (i.e. ramp, shaft or borehole access);</li> <li>- intensive application of artificial barriers;</li> <li>- heat emission is considered in design;</li> <li>- package for SF/HLW/ILW – be sure.</li> </ul>	SF; HLW; ILW; LLW; VLLW; (NORM; TENORM) – solid	Geological disposal
UF-2	<ul style="list-style-type: none"> <li>- no direct, open connection with surface during construction or operation stage (i.e. ramp, shaft or borehole access);</li> <li>- rather wide application of artificial barriers;</li> <li>- heat emission is not considered in design;</li> <li>- package for ILW – be sure.</li> </ul>	ILW; LLW; VLLW; (NORM; TENORM)	Disposal on intermediate depth + geological disposal + borehole disposal
<b>NSF</b>			
NSF-1	<ul style="list-style-type: none"> <li>- open air at construction stage; sometimes also during operation;</li> <li>- rather wide application of artificial barriers;</li> <li>- heat emission is not considered in design;</li> <li>- package for ILW – be sure.</li> </ul>	ILW; LLW; VLLW; (NORM; TENORM)	Near-surface disposal + disposal on intermediate depth (particularly)



## 7. Methodology

### 7.1. The presenting scheme

The presenting scheme was developed by the Expert Group on Waste Inventorying and Reporting Methodology (EGIRM) as a tool for presenting the national spent fuel/radioactive waste (SF/RW) inventory in conjunction with the national strategy for SF/RW management.

This scheme represents a means to present the combined SF and RW inventory as established by the country strategies for waste management in relation to disposal solutions. In other words, once completed by the country, this scheme presents the real picture of SF/RW management in the country during the period of reporting.

This scheme is also suitable for forecasting future inventory and country strategies, if needed. The scheme developed for SF and RW after reprocessing of the SF management is provided in Table 9.

### 7.2. Methodology of the presenting scheme application

#### 7.2.1. Format of data presenting

In terms of the RW volume to be reported, a task can be considered from two points of view:

- inventory data; and repository capacity.

To provide real, adequate comparability of data from the point of view of the repository capacity, it is reasonable to request that countries provide volumes of the conditioned RW ready to be disposed of in the corresponding table cells.

In this case, final volumes of conditioned RW ready to be disposed of will be considered. On the other hand, the following situations are also possible:

- There is no current technology available for the industrial processing of some types of RW (for example, graphite) and it is thus problematic to recalculate the “raw” volume into any conditioned form.
- There are currently no certified disposal containers for some kinds of RW but the technology for processing exists, and hence only the volume of the matrix can be calculated.

- There is a considerable amount of RW (for example, some kinds of “legacy” waste) for which no management strategy is currently established, and it is difficult to calculate the conditioned volume.
- Some countries have included RW into their inventory “as stored” but repacking before the disposal may or may not be envisaged; in this case, recalculation may be problematic.
- “Disposal capacity” of a repository may be stated in terms of the “as stored” volume of waste or the number of primary waste packages; the volume of any added disposal packaging is considered to be part of the disposal engineered system, not the waste volume and is not considered in the national inventory calculation. (e.g. the capacity stated in “number of drums”, rather than xx m<sup>3</sup>.)
- Other situations.

**Table 9. Table of the RW presenting scheme**

Spent fuel and radioactive waste inventory presentation

Country: \_\_\_\_\_

Date of inventorying: \_\_\_\_\_

Type of spent fuel (SF) or radioactive waste (RW)	Storage while awaiting a strategy	Reprocessing of SF		UF-1		UF-2		NSF-1	
		(C1)	(C2)	(D1)	(D2)	(E1)	(E2)	(F1)	(F2)
(A)	(B)	(C1)	(C2)	(D1)	(D2)	(E1)	(E2)	(F1)	(F2)
1. SF + reprocessing RW									
1.1. Nuclear power plant									
1.1.1. SF (tHM)									
1.1.2. Reprocessing HLW (HE), (m <sup>3</sup> )									
1.1.3. Reprocessing RW (NHE), (m <sup>3</sup> )									
1.2. Other reactors									
1.2.1. SF (tHM)									
1.2.2. Reprocessing HLW (HE), (m <sup>3</sup> )									
1.2.3. Reprocessing RW (NHE), (m <sup>3</sup> )									
2. Other HLW (m <sup>3</sup> )									
3. ** (National RW class) (m <sup>3</sup> )									
4. *** (National RW class) (m <sup>3</sup> )									
5									
Equivalence with IAEA GSG-1 classification (type)				HLW ILW LLW VLLW		ILW LLW VLLW		LLW VLLW	

For the “Status and Trends” project, which is the IAEA’s initiative, two variants of the national RW volume reporting are requested: “as is” and “as disposed”. This means each RW class should be reported in both of these statuses. Of course, when a country cannot present RW “as disposed” it provides the “as is” data. Such an approach seems to be reasonable for issues of global inventorying.

Since the objective of the EGIRM is technical – to provide a comparable presentation of RW amounts only from the point of view of disposal – it makes sense to request that RW inventory data be presented “as disposed”.

Reporting RW in the “as disposed” form (volume) is requested for the methodology. To provide information in this format, a recalculation of volumes can be applied and the package factor accounted for, which means the total RW volume to be disposed of, including the volume of the disposal package except in the case of unconditioned RW. In one country, it may be the container for both transportation and disposal, and in another, just the container for disposal (for example, cans with vitrified HLW). From the point of view of the repository features, the real volume to be disposed of has a value for the assessment of capacity. It is necessary to take into account the different approaches in countries and ask them to provide a so-called BRUTTO volume of the RW for disposal (including package).

However, sometimes it is difficult or impossible to provide the volume in this form for different reasons. For example, it is not clear what kind of container will be used as a disposal container and, hence, the volume of the package cannot be accounted for. In this case, the reporting of a given part of RW in the “as is” form is possible. Such “as is” volume should be included in a total volume in the relevant cell of the table. The total RW amount in this cell should be marked with a figure (superscript) and a relevant explanation should be provided in the footnote where it should be presented as a sum of “as is” and “as disposed” forms.

In addition, in some countries, the volume of the primary waste package (e.g. drum) is considered to be the disposal volume for repository sizing purposes. Any added disposal packaging (e.g. concrete over packs) is considered to be part of the engineered disposal system, not the disposed waste volume.

The same approach could be used when RW exists, for example, in liquid form, since currently recalculation of volumes is impossible or leads to significant uncertainties, or the package factor cannot be accounted for.

The question arises whether all countries have a methodology for the recalculation of volumes from raw to conditioned volume, and thus national profiles and reports from NEA countries were checked. From 24 reporting countries 7 countries have not provided profiles/reports, 14 countries recalculate LLW and ILW raw volumes into conditioned forms (as stored or as disposed). And, only two countries have not given recalculated volumes. This means the practice of recalculation is applied in at least half of NEA countries. In general, recalculation is needed for the RW classes equivalent to the LLW and ILW (in the GSG-1 definition). The VLLW usually is disposed of without conditioning (other than minimal packaging) and does not need recalculation.

It should be noted that, eventually, international initiatives like the Status and Trends project establish the rules of reporting. In this regard, the developed methodology (including the presenting table) is considered as the tool for presenting data, and explanations are given to recommend a universal and simple way to complete the table and to overcome all possible difficulties.

The SF from nuclear power plants (NPPs) and other reactors, and in turn RW after reprocessing, could be inventoried together, and collected and stored together (mixed). For such joint amounts, it is therefore difficult to separate these figures and place them into the relevant SF/RW cells regarding NPP and other reactors.

In this case, the reporting country should make the relevant decision on where to put the SF/RW amount – in the lines under “1” or “2”. This amount should be accompanied by an explanatory footnote.

### **7.2.2. International reprocessing of the spent fuel**

The question arises of how to consider a strategy for the shipment of SF to another country in the presenting scheme.

In this regard, four options for management in another country are possible:

- sent SF to be reprocessed and the resulting RW to be left in the country of reprocessing;
- sent SF to be directly disposed of in the country of the original fuel's origin (service);
- sent SF to be reprocessed and the resulting RW to be sent back to the country of origin;
- sent SF to be stored for a long period awaiting a strategy (repository) and then sent back to the country of origin.

When SF is reprocessed, the resulting RW after reprocessing can be left in the country of the “servicer” or sent back to the country of the “user”.

The issue of reporting SF being reprocessed in another country is explained in detail, and relevant cells in the table are noted below, in the methodology of the scheme's application.

According to the requirements of the Joint Convention (IAEA, 1997) and the EC 2011/70 Directive (EU, 2011), member countries should report SF/RW that is the subject of international agreements on the provision of service (reprocessing). To provide a traceability of international SF/RW management according to requirements, both parties of the agreement should report the amount of SF stored abroad awaiting reprocessing, as well as RW to be sent back to the country of origin.

To ensure the full adequacy of reported data when the current status is reported, countries are requested to include in the relevant cells of the table those amounts of SF/RW that are currently in national inventories. A situation when parties of an international agreement report different amounts of the same SF/RW is possible when there is no mechanism for the timely exchange of data between



parties to the agreement. This can be a reason for governments to develop or improve such a mechanism.

To provide information about the initial amount of SF sent abroad as well as the amount of RW to be sent back to the country of origin, countries are requested to give a brief explanation in the footnote. Explanations and relevant amounts in the table should be accompanied by an explanatory footnote.

When countries provide past summaries, they should include an integral amount of SF/RW serviced under all agreements until the moment of reporting.

When countries provide a future prognosis, they should include the remaining SF awaiting reprocessing abroad and the RW volume to be sent back at a future period specified in the prognosis.

Situations when not only reprocessing could be provided as an international service, but also direct disposal and long-term storage, were considered relevant and could be reported and presented in the table.

For such situations, the same method of reporting is recommended. Countries that are parties to an agreement should include SF/RW in the cells of the table suitable for the service.

For direct SF/RW disposal, countries should use the cells in column D for “servicer” and cells in column C2 for “user” until SF/RW is inventoried in “user”. Both parties should mark this SF/RW with figures (superscript) and give a relevant explanation in a footnote.

For long-term storage of SF/RW, countries should use cells in column B for “servicer” and cells in column C2 for “user” until SF/RW is inventoried in “user”. Both parties should include an explanatory footnote for this SF/RW.

### **7.2.3. Review of the national SF/RW inventory and the SF/RW management strategies**

In order to complete the table, the following information is necessary:

- National SF inventory (NPPs and other reactors). For this table, data should be presented in tHM.
- National RW inventory (in national classification). It is necessary to check the format of data presented in the inventory (m<sup>3</sup>, “as is”, “as disposed”, physical status, stored and disposed of).
- National RW classification transfer matrix into GSG-1 scheme (the majority of countries developed it for use in the NEWMDB).
- National strategy on SF management. It should be an officially stated or declared decision of a level as high as required in the country (law, governmental decree, state programme and other kinds of decisions).
- National strategy on RW management in relation to the final stage – disposal of (disposal routes for the RW classes). The absence of a strategy for some kinds of RW in the context of reporting should also be noted. For

the objectives of the methodology, the management strategy that is officially established by the country should be considered.

- International agreements signed by the country regarding reprocessing or other kinds of service for SF (treatment of RW) abroad/from abroad. Amounts of SF or RW being the subject of such agreements should be presented in the table.

It is necessary to note that all this information is currently provided by the countries in the national reports under the Joint Convention and EC 2011/70 Directive as well. Hence, one of these reports can be used as the main source of information.

#### 7.2.4. Completing the table

All quantities of SF and reprocessing RW should be reported in accordance with the factual situation in the country's inventory on the reference date of reporting.

Before completing the table, it makes sense to compare the national types of disposal facilities with the arrangement proposed for this methodology and attribute the national facilities to the types established for this methodology. This should not require a great deal of effort as the facility arrangement in the methodology is based on very simple criteria.

The purpose and recommendations for completion of the table are given for each line and row in the table. Following this methodology, the table is to be completed, and then it can be used each time when needed to show the current national status in SF/RW management for the period until the next national inventorying.

##### Column (A)

In column (A), a country should input all classes of RW existing in the country (starting from line [3.] and below) in terms of the national classification.

**Important:** the SF should be reported in tonnes of heavy metal (tHM) and RW in cubic metres (m<sup>3</sup>). Disused sealed radioactive sources (DSRS) when specified as a RW class should be reported in pieces (pcs) and a relevant remark should be made in the table.

Position (1.) "SF + reprocessing RW" including all rows and sub rows is fixed for this table and should not be changed. When a country does not have any NPP (or other) SF, then the country should input 0 ("zero") in the relevant lines.

Row (2.) "Other HLW" is for other (not related to the SF reprocessing) HLW that could exist in the country. When such HLW has another title, it should be put instead of "other HLW".

The last row of the table "Equivalence with the IAEA's GSG-1 classification (type)" shows where the respective waste classes (as in GSG-1) fall within the presentation scheme matrix. When several RW classes are to be disposed of in a facility of one type (i.e. put in one column of the table), one should list all equivalent GSG-1 classes at the relevant cell in several lines in order of appearance

from top to bottom. Equivalent classes as those in the GSG-1 can be defined based on the national NEWMDB transfer matrix.

### Column (B)

Column (B) is provided to input the SF or RW for which there is no currently defined strategy. It could be SF/RW placed into a long-term storage facility and awaiting a decision. It also could include the RW collected as a result of past activities (for example, former reprocessing of research reactor fuel) and currently stored in the storage facilities or in the places of origin without a long-term management strategy. Since much of such RW may not be conditioned yet, it is acceptable to input this RW in the form of “as is” (raw or stored volume) with the relevant footnotes. SF is reported in tHM.

**Important:** the SF currently stored and awaiting reprocessing/disposal should not be input into Column (B), since it has a defined strategy.

### Column (C)

Column (C) is provided to input all SF to be reprocessed and the resulting RW from SF that has been reprocessed, including SF sent abroad (for reprocessing or other service) following the provisions of an international agreement. Column (C) is divided into the two sub columns (C1) and (C2).

Column (C1) is provided to input all SF to be reprocessed. This should also include the SF “imported” from the “user” countries and included into the national inventory of the “servicer” country. In the case where the “servicer” provides another service to the “user”, the amount of SF is to be put in other relevant columns.

It is important to note that any RW obtained as a result of the SF reprocessing, stored and inventoried currently at the “servicer” country with the intention to be sent back to the “user” country (at a later time) should be put into the cells of this sub column by the “servicer” country.

To facilitate an understanding of the information in this sub column, it is proposed that the “servicer” country present the amount of SF as a sum where components are their own SF and the SF imported from different “user” countries with their country code top-level domain (ccTLD) (see the national tables in Annex 1). The same is proposed for RW intended to be sent back to the “user” countries.

The “user” country inputs its own SF to be reprocessed abroad (in the future), while being stored and inventoried in their (i.e. “user”) country, within this sub column.

A relevant reference on agreement and the role of the reporting country (“servicer” or “user”) should be provided in the footnote.

Column (C2) is provided to input SF currently being reprocessed abroad and reflects what is currently stored and inventoried in the “servicer” country. This quantity of SF is to be input by the “user” country into the relevant cells.

In addition, the “user” country should include in the relevant cells of this sub column RW obtained after SF reprocessing, inventoried to the date of reporting and to be returned to the “user”.

When the “user” country has sent its SF to several “servicer” countries, SF should be presented as a sum (see above). The same should be done for the RW obtained and to be returned by the “servicer” countries.

Hence, the sub column (C2) is only valid for countries that have an international agreement on reprocessing (or other service) of SF as a “user” country and have sent the SF abroad. A relevant reference on agreement and the role of the reporting country (“user”) should be provided in the footnotes.

#### *Column (D)*

Column (D) is provided to input SF that is to be directly disposed of, HLW and RW decided to be disposed of into a UF-1 facility. Column (D) is divided into the two sub columns (D1) and (D2).

Column (D1) is provided to input SF from NPPs (level - 1.1.1.) and other reactors (level - 1.2.1.) to be directly disposed of in accordance with the decided strategy. Since UF-1 is the only acceptable path to dispose of SF and HLW, the HLW amount should also be put into relevant cells of this sub column.

**Important:** the SF/RW currently being stored awaiting a disposal facility UF-1 should be put into (D1).

When a country decides to dispose of other types of RW (from HLW to VLLW) in the UF-1, they should all be put into the relevant cells of (D1). It is preferred that all of the RW amounts should be input in the form of “as disposed”.

Column (D2) is provided to input the SF/HLW amounts or other waste that are already disposed of in the UF-1 facilities. Since there are no operating UF-1 facilities (for SF or HLW), this sub column is highlighted and should not be completed until the UF-1 is implemented.

#### *Column (E)*

Column (E) is provided to input all RW to be disposed of and already disposed of in a UF-2.

Column (E1) is provided to input RW to be disposed of in a UF-2 facility. Each RW class, except HLW (HG) and SF, can be put into the relevant cell of (E) if, in accordance with the decided strategy, it is to be disposed of in a UF-2. It is preferred that all the RW amounts should be input in the form of “as disposed”.

Column (E2) is provided to input the RW amounts that have already been disposed of in a UF-2 facility. As an example of a UF-2, the WIPP facility in the United States, the Batapaati facility in Hungary or the SFR facility in Sweden could be mentioned.

#### *Column (F)*

Column (F) is provided to input RW to be disposed of and already disposed of in a NSF-1 facility.

Column (F1) is a specific column provided to input the RW amount to be disposed of in a NSF-1 facility. Typically, this type of facility is used to dispose of LLW and lower classes. However, when a country decides to dispose of ILW (normally only LLW) in the NSF-1, it should be put in this sub column.

The RW amount is preferred to be reported in “as disposed” form.

Column (F2) is given to input RW disposed of in the NSF-1 facilities.

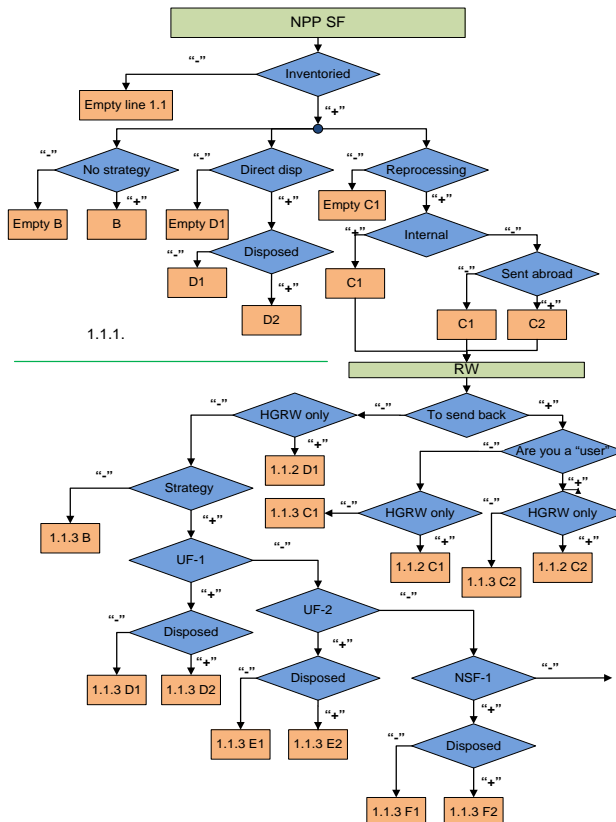
As an example of such a facility, Centre de l’Aube in France, El Cabril in Spain or Rokkasho in Japan could be used.

**7.2.5. Flowchart for completion of the table**

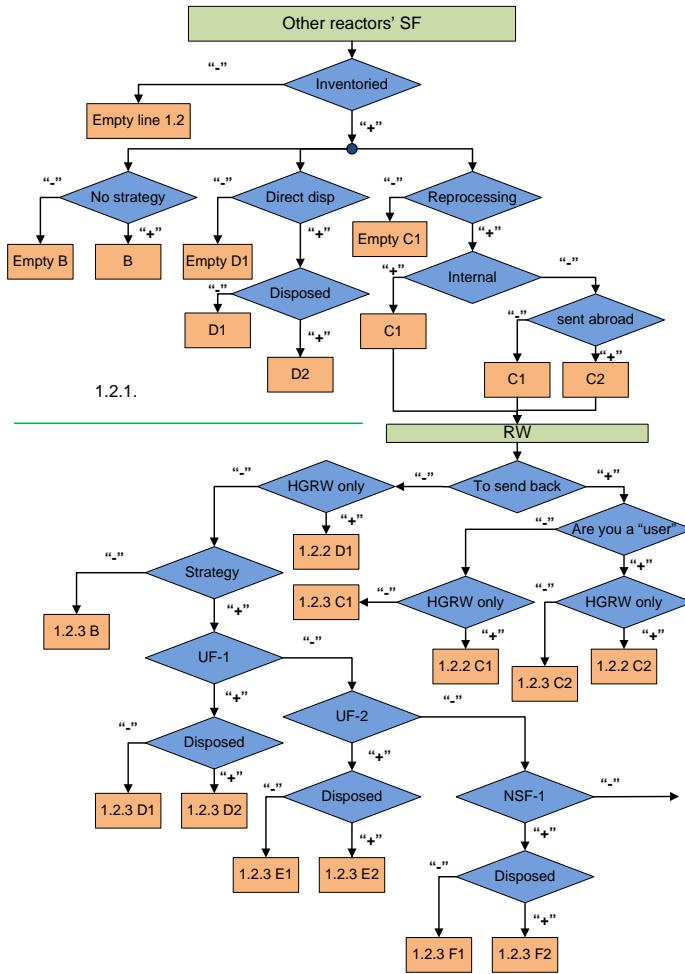
To facilitate the process of completing the table, a block diagram (flowchart) was developed to outline the process to define the cell for a given kind of SF/RW.

Two variants of the flowchart are given below. One is for NPPs SF and RW after reprocessing. The second is for SF from other reactors. (See Figure 2 and Figure 3, respectively)

**Figure 2. The block diagram (flowchart) for the NPP SF table**



**Figure 3. The block diagram (flowchart) for the table related to other reactors' SF**



In both flowcharts, the area over the green line is for line notes on this line (1.1.1. and 1.2.1), and below these lines the cells are specified for each case of the diagrams in format "line - column" (1.1.2. D1).

- "-" means "no".
- "+" means "yes".

The cases when SF is a subject of international management, except for the reprocessing (disposal or storage), are not considered in these flowcharts. When such practices are implemented, the flowcharts can be updated.

## 8. Testing of the methodology

After approval of the presentation scheme proposed by the Expert Group on Inventorying and Reporting Methodology (EGIRM), the testing of the methodology started. EGIRM participants tested the methodology and completed the scheme with data related to spent fuel (SF) and radioactive waste (RW) after SF reprocessing in their respective countries.

The methodology testing was limited to SF and RW after reprocessing of SF, as decided by the Radioactive Waste Management Committee (RWMC).

The methodology was tested on national programmes of different sizes. Expert group members from Belgium, Canada, France, Germany, Italy, Russia and the United States applied the methodology and presenting scheme to reflect the situation with SF/RW management in their countries.

Additionally, two further volunteer countries participated in testing: Spain and the United Kingdom provided comments.

Results of testing were collected and analysed by experts and the expert group then performed an update of the methodology. One of the objectives of this testing was also to determine what problems or difficulties that the methodology user might encounter when filling out the scheme.

The main observations made during the testing of the methodology were:

- the methodology works well for SF and RW inventories of countries with a large diversity of nuclear programmes;
- all kinds of national SF and RW management strategies can be presented with the methodology;
- a good capacity to improve clarity was provided through footnotes, where experts gave brief essential explanations about the content of cells marked by numbers in superscript;
- there were some difficulties in completing the cells C1 and C2, and additional clarification was provided in the methodology;
- there was some difficulty in completing the cells when RW volumes were inventoried either “as is” or “as disposed” and a solution was proposed in the methodology;
- it was sometimes difficult to distinguish the SF from nuclear power plants and other reactors and RW respectively; recommendations were provided;

- since the benefits from the methodology's implementation were unclear for some countries; the expert group formulated and included a relevant chapter in the report;
- since the use of the table and methodology were not entirely clear for users; additional clarification was developed and included in the text of the methodology.

All solutions to the difficulties were included in the text of the methodology as updated provisions.

The testing demonstrated good workability of the developed scheme and methodology. The form of the presenting scheme was developed to address all possible scenarios of SF and RW after reprocessing management, including those not implemented currently. The ability to cover all types of SF and RW after reprocessing was also confirmed. Testing allowed for an understanding of the need to improve the text of the methodology to make it less ambiguous and clearer for users. Flowcharts developed and included into the methodology gave additional understanding on how to complete the cells of the presenting scheme. The text of the methodology was updated by the experts to be better understood by users and to avoid any misinterpretation.



## 9. Benefits of implementation and potential users

During the methodology development process, members of the Expert Group on Waste Inventorying and Reporting Methodology (EGIRM) considered the benefits that countries can receive after the implementation of the developed table and methodology. Detailed below is the list of potential benefits for users:

- The presentation scheme (table) provides the most comprehensive view of spent fuel/radioactive waste (SF/RW) management in a specific country. It could also be added to the national inventory report as a simplified universal source of information about SF/RW management in a country.
- A populated table for a country can be used for reporting in different international programmes (as required by the Joint Convention [IAEA, 1997] and EC Directive [EU, 2011]) as an illustration of the current status of SF/RW management in the country, a summary of past developments and a future forecast (separate table for each option) during the established periods between the updates of the national inventory.
- The table provides information on the scope and size of tasks and challenges in SF/RW management, better visibility and understanding of status in SF/RW management from different points in time – past, present and future; it could also be useful as a tracking tool for transboundary movement of SF/RW and for monitoring the progress of international radioactive waste management services as well, facilitating identification of uncertainties related to the lack of communication between the parties of an international agreement.
- The table combines SF and RW inventories and presents them through diverse national management strategies.
- The table and methodology can be used for compilation and aggregation of data from different countries on different levels; the developed table could be used as an integral form that could facilitate comparing SF/RW management with the situation in other countries (regions, organisations, etc.); it also could be used as one of the forms to be completed during national inventorying by all RW producers (owners).
- The table can be useful for national and international experts as:
  - an official source of information presented in a standardised format;
  - a useful tool and reference for analysis of the national situation, implementation for national reporting under the international

programmes (Joint Convention, EC Directive, international conferences, symposiums, etc.);

- an easy way to compare their own SF/RW management approaches with other countries on different levels (individual, group, region, organisation, global) to develop adequate proposals to government, national strategies and programmes including economic, management, infrastructural planning;
- a tool for the facilitation of an international dialogue among experts, as well as among stakeholders inside a country.

For international programmes and initiatives (Joint Convention, EC Directive, Status and Trends project, “Brown Book”, etc.), this table and methodology can be useful for the following reasons:

- the table and methodology will be proposed to international organisations such as the IAEA and the EC as an addition to the GSG-1 tool for better harmonisation and unification of national and international SF/RW inventory data;
- the table and methodology provide better comparability of inventories and management strategies accepted in different countries; data given in one table can provide a view of the real situation in a country regarding management of all kinds of SF, RW and disused sealed radioactive sources (DSRS);
- the table and methodology can be used for presenting a compilation and aggregation of data from countries on different levels and in different time frames (past, present or future); they can be used to create integral tables presenting the analysis in initiatives such as the Status and Trends project;
- if used in the national reports for international programmes and initiatives, the table will provide consistency and unambiguity of national data.

The EGIRM also attempted to specify the circle of potential users of the table. The following groups of users were defined as interested in such a tool:

- state decision makers – to have the full picture of SF/RW management in their own country and in others (when needed) in a comparable format;
- national experts (implementer, regulator, researcher, etc.) – to have one authoritative and referable source of information given in a common format;
- international experts – to make an analysis of international practices; find the trends, common and specific features of SF/RW management and to specify “best practices”;
- environmental specialists – to be consistent with “official” data in their analysis and dialogue with implementers;
- non-technical stakeholders (citizens, communities, local authorities, etc.) – to understand the situation in a country and to have consistent data for the dialogue with implementers.

## 10. Conclusions

EGIRM work has been completed in accordance with the mandate and programme of work; the presenting scheme has been developed with a preliminary focus on spent fuel (SF) and the resulting radioactive waste (RW) after SF reprocessing management.

All existing NEA country strategies for the management of SF are covered through this methodology, as well as the management of RW after reprocessing; international SF reprocessing was also considered in accordance with the requirements of the EC 2011/70 Directive.

The EGIRM used unified units, forms and notations to allow comparability of national inventory data as much as possible.

The EGIRM successfully combined in one form the options for presenting the SF inventory as well the RW inventory; both inventories are presented in a scheme in direct relevance with the disposal strategy for each type of SF/RW.

To facilitate use of the presenting scheme, the methodology was developed with detailed instructions on how to fill in the table. The methodology includes the arrangement of disposal facilities developed by the EGIRM. This arrangement is based on simple and clear technical features that allow quick and unambiguous attribution of the national types of facilities to the proposed common arrangement.

The presenting scheme and methodology were developed by the EGIRM as a useful and additional tool to support international programmes in the collection and aggregation of the national SF/RW data. As it is based narrowly on the technical aspects of SF/RW management (especially disposal stage), the methodology can give an additional opportunity to harmonise and present the national data in the framework of each international programme.

The methodology was tested by EGIRM members and some volunteering countries on their own national inventories. Testing demonstrated the workability of the methodology for a wide variety of programmes, strategies and classifications.

The further extension of the methodology is anticipated to be approved by the Radioactive Waste Management Committee (RWMC) to cover all existing SF/RW types (classes), management strategies and disposal routes.



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## Annex 2. List of abbreviations and acronyms

DGR	Deep geological repository
EC	European Commission
EGIRM	Expert Group on Waste Inventorizing and Reporting Methodology
EW	Exempt waste
HLW	High-level waste
IAEA	International Atomic Energy Agency
ILW	Intermediate-level waste
LILW	Low- and intermediate-level waste
LL	Long-lived
LLW	Low-level waste
MS	Member states
NEA	Nuclear Energy Agency
NORM	Naturally occurring radioactive material
NPP	Nuclear power plant
OECD	Organisation for Economic Co-operation and Development
RW	Radioactive waste
RWMC	Radioactive Waste Management Committee
SF	Spent fuel
SL	Short-lived
VLLW	Very low-level waste
VSLW	Very short-lived waste

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# National Inventories and Management Strategies for Spent Nuclear Fuel and Radioactive Waste

Radioactive waste inventory data are an important element in the development of a national radioactive waste management programme since these data affect the design and selection of the ultimate disposal methods. Inventory data are generally presented as an amount of radioactive waste under various waste classes, according to the waste classification scheme developed and adopted by the country or national programme in question. Various waste classification schemes have thus evolved in most countries, and these schemes classify radioactive waste according to its origin, to criteria related to the protection of workers or to the physical, chemical and radiological properties of the waste and the planned disposal method(s).

The diversity in classification schemes across countries has restricted the possibility of comparing waste inventories and led to difficulties in interpreting waste management practices, both nationally and internationally. To help improve this situation, the Nuclear Energy Agency proposed to develop a methodology that would ensure consistency of national radioactive waste inventory data when presenting them in a common scheme. This report provides such a methodology and presenting scheme for spent nuclear fuel and for waste arising from reprocessing. The extension of the methodology and presenting scheme to other types of radioactive waste and corresponding management strategies is envisaged in a second phase.