INVENTORY DOMAIN INSIGHT

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OVERVIEW

The objective of radioactive waste management is to account for and control radioactive waste to protect human health and the environment and to ensure unnecessary burdens are not left for future generations. In order to do this it is essential that the nature and quantity of the radioactive waste, i.e. the inventory, generated from legacy or ongoing programmes or to be generated in the future is understood. An inventory represents a toolkit to collate the relevant information in an accessible form that can be maintained over significant periods of time associated with the generation, storage, treatment and eventual disposal of radioactive waste. When considering what information should be included in an inventory of radioactive wastes it is advantageous to understand the wide range of stakeholders who would wish to use such an inventory, namely:

- **Waste Producers/Owners** who are accountable for the safe management (storage, treatment and eventual disposal) of the waste
- ***Government Departments and Agencies*** who develop policies and strategies for managing waste and who regulate nuclear operations
- ***Supply chain organisations*** who process waste and need data to support the planning, operation and performance of their facilities
- ***Waste planners*** who are responsible for ensuring that waste management facilities meet local and national needs
- ***Researchers and academics*** who are developing innovative technologies and processes for managing radioactive waste
- ***Members of the public*** who would like to understand more about radioactive waste

To enable inventory information to be reported with the right level of detail, a basic set of parameters should be identified and used where applicable. The production of data can be iterative, firstly to recognise the waste streams that the programme will generate, assessing the impact of these on management and disposition. Therefore, it should be recognised that the list of parameters that form the inventory may evolve over time. As a consequence, an inventory typically includes the following information for each radioactive waste stream

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(based on UKRWI[1] and comparison of inventories across EU[2] and the IAEA member states[3])

- Name of the waste producer or owner
- Location of the waste
- Name of the waste
- A unique identification code
- Waste classification
- Volume in stock at a given reference date
- Volumes forecast in the future and the timing of these arisings
- Physical and chemical composition
- Radioactivity and radionuclide composition
- Current or planned treatment and packaging
- Current or planned disposal route.

Full information about each waste stream will be contained within individual data sheets, usually in forms generated in an electronic spreadsheet or/and a Portable Document File (pdf). Additionally, hard copy records are produced on media suitable for long-term archiving of the data so that future generations have a robust record of the radioactive waste that was produced, where it was (temporarily) stored, treated and subsequently disposed to[4].

A Radioactive Waste Inventory (RWI) may be typically constructed within formal contracts under waste management systems between waste producer, consignor and receiver, and overseen by the relevant regulatory bodies. The RWI may be applicable to a single waste item, a collection of waste items or a contained volume of material.

The fundamental requirement of an RWI as a dataset is that it provides, with a reasonable degree of confidence, the information needed at each of the various stages of the waste's lifecycle and demonstrate accountancy of the materials used in the programme. This need could range from a modelled inventory prior to its generation simply to aid planning purposes, to a fully-developed inventory of a final waste package that is appropriately well characterised to meet safe levels of waste management through storage and transport to a final disposal location. The final package inventory as described may be the basis, or the only information offered to future generations, fora continued safe management of these waste packages.

KEYWORDS

waste, inventory, categorisation, waste processing, storage, disposal, safety, radiation protection, records

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[1] UK Radioactive Waste Inventory. https://ukinventory.nda.gov.uk/. Accessed 14 June 2023.

[2] ENER/2018/NUCL/SI2.778797, 'Benchmarking Analysis of Member States Approaches to Definition of National Inventories Radioactive Waste and Spent Fuel', Final Report February 2020. ISBN: 978-92-76-27383-7, DOI: 10.2833/460048, MJ-06-20-177-EN-N.

[3] https://www.iaea.org/resources/databases/spent-fuel-and-radioactive-waste-information-system-sris.

[4] Waste inventory record keeping systems (WIRKS) for the management and disposal of radioactive waste; IAEA-TECDOC-1222; 2001

KEY ACRONYMS

ALARP	As Low As Reasonably Practicable
DGR	Deep Geological Repository
DI	Domain Insight
FEP	Features, Events and Processes
GBS	Goals Breakdown Structure
HAW	Higher Activity Waste
HLW	High Level Waste
IAEA	International Atomic Energy Agency
ILW	Intermediate Waste
LAW	Low Activity Waste
LLW	Low Level Waste
MS	Member State
NEA	Nuclear Energy Agency, part of OECD
NPP	Nuclear Power Plant
OECD	Organisation for Economic Co-operation and Development
PIP	Planning and Initiation Program
POCO	Post Operational Clean Out
PREDIS	Pre-disposal Management of Radioactive Waste (EC project)
PSWP	Product and Secondary Waste Plan
RAM	Radioactive Material
RW	Radioactive Waste
RWI	Radioactive Waste Inventory
RWM	Radioactive Waste Management
SF	Spent Fuel
SQEP	Suitably Qualified and Experienced Person
WAC	Waste Acceptance Criteria
WMH	Waste Management Hierarchy

1 TYPICAL OVERALL GOALS AND ACTIVITIES IN THE DOMAIN OF INVENTORY

This section provides the overall goal for this domain, extracted from the EURAD Roadmap goals breakdown structure (GBS). This is supplemented by typical activities, according to phases of implementation, needed to achieve the domain goal. Activities are generic and are common to most regional and geological disposal programmes.

Domain Goal	
2.1.1 Evaluate waste inventory from generators and existing storage, accounting for future waste generation and evolution (Inventory)	
Domain Activities	
Phase 1: Planning and Programme Initiation	Developing an accurate inventory demonstrates to all stakeholders that the waste producer has a good knowledge of the RW to be managed and that all processes in place to manage the RW can be demonstrated. Knowledge of the RW likely to be generated and its radiological and non-radiological composition is important to inform • All necessary risk and safety assessments • the efficacy of the desired treatment process • and the facility can be commissioned • the waste meets the waste acceptance criteria (WAC), and thus the safety case, for the receiving facility (whether treatment or disposal) The inventory estimate should be periodically assessed and altered, as appropriate, to reflect any change in the RW's properties through the full lifecycle of RWM from raw arisings, through storage and final conditioning and packaging. The concept of Integrated Waste Management should be considered to look for opportunities to optimise the processes and to apply the fundamentals of the waste management hierarchy. For final disposal this ties in with the DI of Characterisation [5] [6]. A key element to all of this is a good records management system to identify the inventory data

[5] Characterization of Radioactive Waste Forms and Packages. IAEA Technical Reports Series No. 383. STI/DOC/010/383 ¦ 92-0-100497-4. 1997.

[6] Radiological Characterisation for Decommissioning of Nuclear Installations; Final Report of the Task Group on Radiological Characterisation and Decommissioning (RCD) of the Working Party on Decommissioning and Dismantling (WPDD). Radioactive Waste Management. NEA/RWM/WPDD(2013)2. September 2013.

	and to capture the collated inventory data for reporting and assessment [7] [8] [9]. It is also important to demonstrate how all materials and waste are accounted for. For reporting at the National or International level, NEA has developed a common template for the reporting of Spent Fuel and Radioactive Waste[10] [11].
Phase 2: Program Implementation	The inventory is essentially the collection of information sets and data required to assess and demonstrate the safe management of RW as it is generated and to also progress management of the waste to the next step in the RWM lifecycle. The inventory should be developed using a combination of modelling tools using appropriate source data[12], sampling and characterisation, provenance, and expert judgement. The ongoing management is determined by the waste properties and its Classification[13]. Understanding the requirements for the next phase in RWM and the controls and data requirements in place for the current step, help to identify those data necessary to be acquired to produce an effective inventory at this program implementation stage. The collective production of RW within each Member State is important to ensure that appropriate measures for RWM are in place at the State level, allowing all potential disposition routes to be assessed and State-level Strategic Studies to be based on a complete and accurate national inventory dataset.

[7] Methods for Maintaining a Record of Waste Packages During Waste Processing and Storage. IAEA Technical Reports Series No. 434, STI/DOC/010/434 ¦ 92-0-114704-X. 2005.

[8] Record Keeping for the Decommissioning of Nuclear Facilities. IAEA Technical Reports Series No. 411. STI/DOC/010/411 ¦ 92-0-119602-4. 2002.

[9] Long Term Preservation of Information for Decommissioning Projects. IAEA Technical Reports Series No. 467. STI/DOC/010/467 ¦ 978-92-0-101808-3. 2008.

[10] IAEA Nuclear Energy Series No NW-T-1.14 (Rev. 1). Status and trends in Spent Fuel and Radioactive Waste Management. 2022.

[11] NEA (OECD) National Inventories and Management Strategies for Spent Nuclear Fuel and Radioactive Waste; 2017.

[12] Nuclear Energy Agency (NEA) Data Bank – an international reference centre for computer codes, nuclear and thermochemical data.

[13] Classification of Radioactive Waste. IAEA Safety Standards Series No. GSG-1. STI/PUB/1419 ¦ 978-92-0-109209-0. 2009.

	(see Waste Hierarchy, Transport, Storage, and Disposal DI's)
Phases 3–4: Program Operation/Optimisation and Closure	The inventory should be regularly reviewed for its appropriateness and its validity to represent the waste being generated. It can be expected that waste inventory requirements, typically governed by WAC issued by the Operators of a final disposition facility may be subject to change as they periodically review and update their safety case and the RWI may require modification to reflect this. The opportunity to revise the process to optimise[14] the wastes generated should be included as part of inventory review strategy to undertake: • Validation (retrieved/processed v planned) • Value realisation- show that waste minimisation has been achieved and where value is recovered • Demonstrate that future safety is being ensured through reduction in the hazard potential of the waste. At end of operations review proposed POCO/Decommissioning strategy/plans against operational history and revise them as necessary. Implement POCO/Decommissioning strategy/plans.

2 INTERNATIONAL LEGISLATION

The EU Directive is typically embedded into one or more governmental national policies in order to provide a radioactive waste and spent fuel management framework that can be appropriately regulated.

- EU Council Directive 2011/70/EURATOM. Establishing a Community Framework for the responsible and safe management of spent fuel and radioactive waste

Alongside the EU directive and national policies, there are a number of IAEA Joint Convention and IAEA Safety Series documents that provide important guidance for the development and reporting of spent fuel and radioactive waste inventories to plan. Whilst not legislative documents to adhere to, it is highly recommended that this guidance is appropriated where it pertains to RWI and does not conflict with national policies.

[14] Multifactor Optimisation of Predisposal Management of Radioactive Waste. Proceedings of the NEA Joint Workshop 10-14 February 2020 OECD Conference Centre Paris. Radioactive Waste Management and Decommissioning. NEA/RWM/R(2020)3. June 2021.

Section 2.3 of the 2022 publication of the IAEA Status and Trends report provides a recommended list of Safety Series and other useful documents from the Nuclear Safety Series, some of which are shown below;

- *IAEA (1997), "Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management", INFCIRC/546.*
- *IAEA (2012). 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. INFCIRC/604/Rev.2.*
- *IAEA (2016). Government, Legal and Regulatory Framework for Safety; SSR-2/2 (Rev. 1).*
- *EC (1999). European Commission Recommendation on a Classification System for Solid Radioactive Waste, SEC(1999) 1302 final.*
- *EC (2011). Seventh Situation Report Radioactive Waste and Spent Fuel Management in the European Union SEC(2011) 1007 final.*
- *ENSREG (2014). Final Guidelines for MS Reports to the Waste Directive, HLG, p(2014-27)_137.*
- *IAEA (2010). Guidance on Translation of Member State Waste Classes for Purposes of Reporting Waste Inventories to the Net-Enabled Waste Management DataBase, unpublished.*
- *IAEA (2009) Predisposal Management of Radioactive Waste. General Safety Requirements No. GSR Part 5.*
- *IAEA (2019). Predisposal Management of Radioactive Waste from the Use of Radioactive Material in Medicine, Industry, Agriculture, Research and Education; Specific Safety Guide SSG-45.*
- *IAEA (2023). Integrated Life Cycle Risk Management for New Nuclear Power Plants.*

Transport

IAEA Safety Standards (2018). Regulations for the Safe Transport of Radioactive Material. Specific Safety Requirements. No. SSR-6 (Rev. 1) 2018 Edition

International Regulations

IAEA SSG-44[15] Establishing the Infrastructure for Radiation Safety – this recommends that regulatory states mandate the establishment of inventories.

Classification of Radioactive Waste (RW)

Key to developing an effective inventory of radioactive waste is to have a consistent system of radioactive waste classification. This was first established by the IAEA in 1994 in Safety Series 111-G-1.1 [16]. According to IAEA guidance provided in Safety Standards Series No. GSG-1, Classification of Radioactive Waste [3], the requirements for the management and disposal of radioactive waste are dependent upon its classification: high (HLW), intermediate (ILW), low (LLW) or very low level

[15] Establishing the Infrastructure for Radiation Safety; IAEA Safety Specific Guide No. SSG-44

[16] Classification of Radioactive Waste, SS 111-G-1.1 (IAEA, 1994)

waste (VLLW). The final disposal of the waste may range from geological disposal for HLW to near surface trench disposal for VLLW. The activity level and the nature of radionuclides in the waste, as well as waste properties, determine the conditioning needs of the waste before disposal or, as the case may be, release from regulatory control.

Subsequently, these classes were modified in **Classification of Radioactive Waste, GSG-1 (IAEA, 2009).** Some of the quantitative criteria of the classification system were removed and the descriptions made more qualitative. This allows greater flexibility for countries to adopt site-specific boundaries between classes that are more suited to their infrastructure and regulatory needs. The new boundaries are shown in Figure 1.

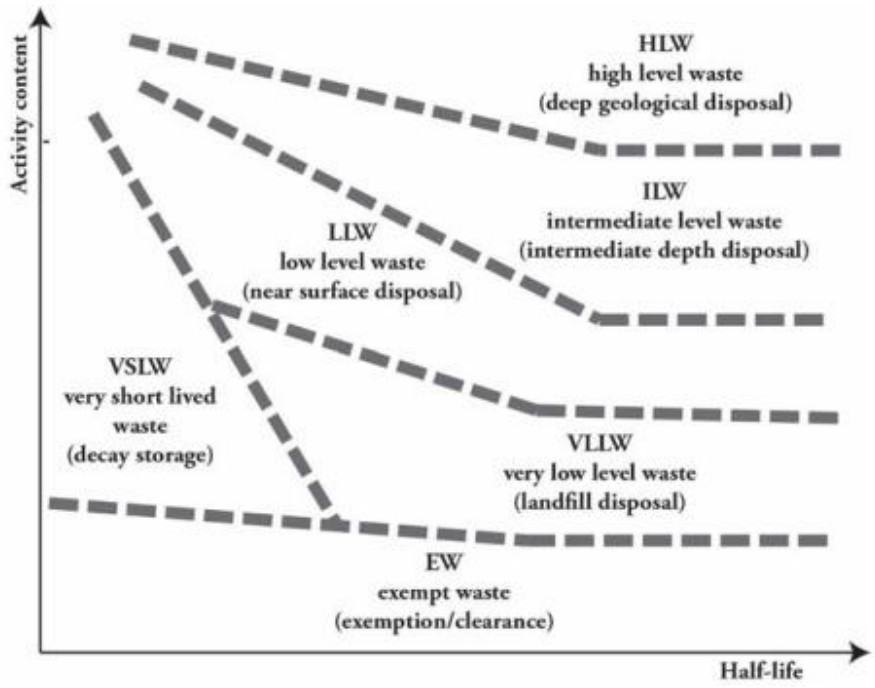

Figure 1 Illustration of RW classification boundaries[17]

EU Regulations

In accordance with Article 11 and Article 12 of Council Directive 2011/70/Euratom[18], Member States shall develop and implement national programmes for spent fuel and radioactive waste management that implement in practice the national policies - from generation to disposal of these materials. The Directive requires that the

[17] International Atomic Energy Agency, Status and Trends in Spent Fuel and Radioactive Waste Management, Nuclear Energy Series No. NW-T-1.14 (Rev.1); STI/PUB/1963 ¦ 978-92-0-130521-3, IAEA, Vienna (2022).

[18] Council Directive 2011/70/Euratom establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste. Official Journal of the European Union L 199, 2 August 2011, pp. 48-56.

national programme shall include among others "an inventory of all spent fuel and radioactive waste and estimates for future quantities, including those from decommissioning, indicating the location and amount of the radioactive waste and spent fuel in accordance with appropriate classification of the radioactive waste" (see Article 12(1)c). In addition, Member States shall report on the implementation of the Directive every 3 years (starting 23 August 2015) and on the basis of these reports the Commission shall report the EU inventory and the future prospects to the Council and the European Parliament.

Other Domains list **(Waste Acceptance Criteria, Characterisation, Treatment Conditioning, Storage, Transport)**.

3 GENERIC SAFETY ISSUES

This section describes the safety precautions associated with each of the predisposal stages, from program planning and initiation (3.1), through active commissioning (program implementation - 3.2) into operational and closure phases (program operation and closure - (3.3), for which inventory data and management will be required. Program implementation is essentially granting permission to proceed, indicating that the inventory is sufficiently known to ensure any risk associated with the inventory and its management throughout the facility's lifecycle is well understood and its range of uncertainty bounded. Each stage should consider the relevant inventory information requirements to substantiate the safety claims and arguments for nuclear, environmental and conventional safety. For certain facilities a full life cycle risk management approach may be warranted[19].

Figure 2 illustrates the stages in the plant life cycle where inventory data can be obtained and specifies the type(s) of information that can be obtained at each stage.

Importantly, the initial stages relate to the development of a baseline dataset, should regulations require that the land is returned to this baseline state after use. Such a dataset will also support ongoing environment assessments concerning the loss of material to ground and the local groundwaters.

[19] IAEA, 2023. Integrated Life Cycle Risk Management for New Nuclear Power Plants

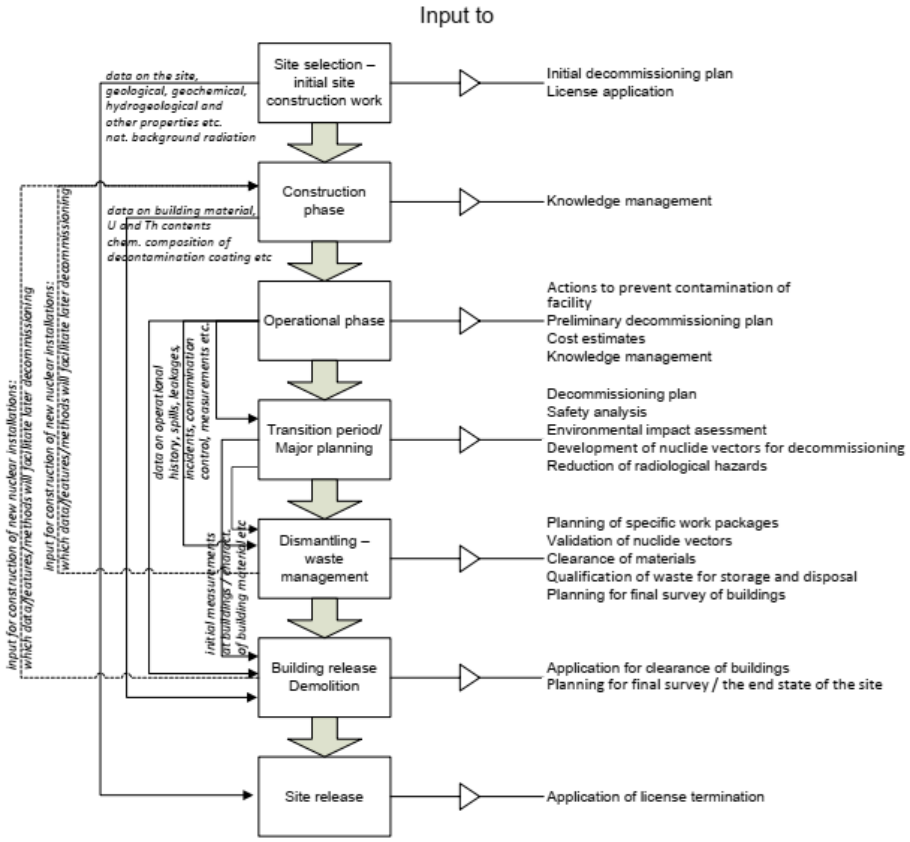

Figure 2: Radiological characterisation/inventory inputs to phases in a plant life cycle. Taken from NEA/RWM/WPDD(2013)2[20]

Clearly all phases of the plant life-cycle provide potential opportunities to determine the waste inventory or confirm the inventory and thus remove uncertainties. This also aligns with the regulatory requirement for reviewing inventories on a three yearly cycle [2]. National programmes may also require period review as to whether the accuracy of the reported inventory remains to an acceptable tolerance for the safe management in its current location or during subsequent disposition.

3.1 Planning and Program Initiation

In the early phases of program initiation, it is necessary to consider the full 'life cycle' of the processes that may require the management of wastes or nuclear materials. A conceptual understanding can be developed that allows the Features, Events and Processes (FEPs) of the programme to be identified and the necessary related inventory data determined.

[20] NEA/RWM/WPDD(2013)2, 'Radiological Characterisation for Decommissioning of Nuclear Installations'. Report of the Task Group on Radiological Characterisation and Decommissioning (RCD) of the Working Party on Decommissioning and Dismantling (WPDD). Final Report September 2013.

The aggregated data for safety assessments within the planning and initiation stage will

- Demonstrate that the program is likely to operate safely with inventories that can be managed within the existing or anticipated waste management controls.
- Ensure that all wastes and materials have identified disposition routes and that the generation of problematic wastes is unlikely.
- Help to identify gaps, or stress points, where data may not robustly substantiate the safety claims. Such gaps or failures to substantiate may require further attention before the next phase of Program Implementation can commence.
- Identify the , Spent Fuel (SF), and the types (LLW, ILW and HLW) and volumes of radioactive wastes anticipated to be generated during operations and decommissioning activities.
- Integrate with Characterisation (ref Char DI) strategy and Waste Hierarchy (Ref WMH DI), to ensure optimisation is fully considered and demonstrated.

Tools and techniques are available to assist in the identification and assessment of inventory requirements at this stage. As well as meeting the safety claims the planning phase should demonstrate that it utilises the best option, e.g. Best Available Techniques (BAT[21], is able to integrate optimisation processes and demonstrate elements of ongoing sustainability.

3.2 Program Implementation

The planning and initiation program may have identified the expected wastes and their associated inventories but the demonstration of the accuracy of these estimates arrives at the program implementation stage.

Monitoring and measurements, identified to support the safety case, should be in play, providing useful inventory data. This should be coupled with the implementation of the ongoing characterisation strategy to commence the development of actual inventory datasets to support the safe management of wastes and nuclear material from this point, through treatment, conditioning, storage and final disposal.

Getting closer towards actual operation of facilities and handling of radioactive waste streams, it is critical to understand the waste handling requirements and crucially how the waste material may change during each handling or treatment operation. Prior to actual movement of radioactive materials, it is necessary to make detailed safety and quality plans and ensure all aspects meet the regulatory requirements. The safety plan must ensure that no harm is done to operators or the environment, whilst the quality plan ensures the efficiency of the process, compliance with WAC for subsequent processing, storage or ultimate disposal it is only through an accurate inventory that that the scale of the hazards associated with the waste will be identified.

In the same way that waste packages typically have a Certificate of Compliance (CoC) from which it can be evaluated if further testing or maintenance is required, any recovered material intended for reuse needs to meet the specifications of

[21] Regulatory Control of Radioactive Discharges to the Environment; IAEA General Safety Guide No GSG-9; 2018.

subsequent processes. This will of course involve confirmation of its chemical composition and physical characteristics but will also involve radiation measurements to ensure that it can be handled in downstream operations, especially if those processes are non-nuclear. Potentially, decay storage may have to be utilised in order to allow short-lived radioactivity to decline so that the material meets the Acceptance Criteria. A regularly updated inventory along with appropriate analysis of the data possible safety risks and scenarios should be documented, including consequence assessments for hypothetical accident cases.

During the implementation phase, inventory issues closely link to the EURAD Roadmap Domain Insight of Storage (2.2.4) which includes issues associated with packaging.

3.3 Program Operation and Closure

Complete construction of facilities/plant identified in the Planning and Initiation Program (PIP), commission facilities and commence operations.

During operation of (pre-disposal) waste management facilities there is a continuous process of reviewing operational performance against the Product and Secondary Waste Plan (PSWP) and application of the waste hierarchy. Determine whether opportunities exist, or can be planned in, to improve the inventory information to ensure that the waste management process is fully informed.

Optimisation of the process may lead to changes in inventories being generated and managed, and within this stage facility management should be aware of the latest RD&D, technology development, changes in international requirements, site licences etc. There may be opportunities to adopt new technologies and practices with regard to handling packages and documentation management. Optimisation of routes for cost and safety may also be periodically enhanced.

Regulatory oversight will continue to evaluate treatment of radioactive materials, including issues like:

- compliance with waste hierarchy and safety precautions towards public and environment,
- documentation of the physical properties of the radioactive material and processing conditions,
- safety and operational performance of the processing facilities and equipment,
- accurate operating procedures applicable to expected waste arisings and non-standard operations,
- accurate characterisation and classification of materials recovered for reuse,
- accurate markings and labelling imposed on wasteforms and packages,
- verifying the recovered materials or wasteform packages are safe for use:
    - Recovered materials comply with specifications for reuse,
    - wasteforms/packages meet WAC for interim stores or disposal sites.

At end of operations review proposed POCO/Decommissioning strategy/plans against operational history and revise them as necessary.

Implement POCO/Decommissioning strategy/plans.

During the operation phase, inventory issues closely link to the other EURAD Roadmap Domain Insights of Characterisation (2.2.1), Quality & Management Systems (2.3.1), Optimisation (2.3.2), Storage (2.2.4), etc.

4 CRITICAL ISSUES, INFORMATION, DATA OR KNOWLEDGE IN THE DOMAIN OF INVENTORY

The benchmarking study[22] of the 2019 submissions of the Member States RW and SF inventories to the EU highlighted the following issues:

- Member States are using different radioactive waste classification schemes (summary is given in Annex II of this benchmarking document). For EU inventory aggregation purposes conversion to a common reporting basis is necessary (IAEA GSG-1 classification[13]). However, conversion from one classification scheme to another often introduces uncertainties, as the radioactive waste classes in different national classification schemes sometimes cannot be directly matched. In such situations, a conversion is carried out on a “best approximation” basis. In the second national reports most Member States reported their radioactive waste inventory using the IAEA GSG-1 classification scheme or provided a conversion matrix allowing conversion of waste inventory from their national classification scheme to IAEA GSG-1.
- Member States use different units (volume, mass, etc.) for unconditioned waste. Conversion from mass to volume without detailed knowledge of radioactive waste treatment/conditioning methods used can result in significant uncertainty. Reporting of disused sealed radioactive sources varies from country to country. Countries with large nuclear programmes generally integrate disused sealed radioactive sources into other large radioactive waste streams and do not report them separately. Countries where the disused sealed radioactive sources make significant part of the national inventory report them separately from the other radioactive waste. In such cases disused sealed radioactive sources are reported only as number of sources.
- Member States report differently volumes of unconditioned radioactive waste – some report actual volumes in storage, while others report estimated volumes after conditioning to be placed in disposal. For inventory aggregation purposes, the estimated volumes of radioactive waste to be placed in disposal are preferred since this represents the final step in management of radioactive waste. Use of actual radioactive waste volumes in storage can lead to significant uncertainties, especially when estimating the need for disposal capacities. Usually, the most significant volume changes (reduction) occur as a result of liquid radioactive waste and sludge treatment and conditioning for disposal. The same is true for combustible and compactible radioactive waste. In the second national reports, most of the Member States provided unconditioned waste estimated volumes for disposal. This allows to reduce uncertainties and to improve consistency and comparability of the data.

[22] Benchmarking Analysis of Member States Approaches to Definition of National Inventories Radioactive Waste and Spent Fuel. No. ENER/2018/NUCL/SI2.778797 Feb 2020.

- Security and Safeguards should be of prime consideration and inventory data management should demonstrate the Safeguarding of Special Nuclear Material and support to non-proliferation activities.

It should be acknowledged that the knowledge level required at the different phases may align to the maturity of the industry and the experiences gained over time. Furthermore, the use of novel materials and their impact on disposability must also be considered. Training may be required to identify such gaps in knowledge and to understand how to address them.

5 MATURITY OF KNOWLEDGE AND TECHNOLOGY

This section provides an indication of the relative maturity of information, data and knowledge for the domain of inventory. It includes the latest developments for the most promising advances, including innovations at lower levels of technology maturity where ongoing RD&D and industrialization activities continue to improve.

Dependent on the size and scale of the industries that generate radioactive waste in the Member State, National Programmes can be used to develop centralised systems that have the benefit of standardising the approach to developing radioactive waste inventories. These are typical led by the waste owners and the waste receivers and overseen by the relevant regulatory bodies.

In the UK, a National Waste Programme, in place since the inception of the Nuclear Decommissioning Authority (NDA) in 2005, led firstly to an Integrated Waste Strategy, followed by an Integrated Waste Management Programme (IWMP) which is currently being implemented. The development of Inventory estimates using tools, both modelling and instrumental, to support this development is well co-ordinated across the industry to enable the sharing of best practice and develop codes of practice. The IAEA Spent Fuel and Radioactive Waste Information System (SRIS) also acts as a repository of such information.

For Member states with less complex waste management requirements and possibly less budget for inventory management, there remains the need to co-ordinate the inventory dataset across the state, perhaps making more direct use of the available IAEA guidance. The level of effort required may be proportionate to the scale and complexity of the program.

Member states with larger and more complex nuclear programmes can more readily produce and accommodate SQEP[23] personnel and new technology in the field of inventory development. The variation of waste types and how these are generated and managed requires significant knowledge and experience covering a number of scientific and engineering disciplines. Such disciplines range from the development of appropriate codes to assess reactor performance on the spent fuel inventory, development of the process flows for chemical treatment of wastes, or inventory required to assess the long-term integrity of the final waste package.

Similarly, the driver to become ever more efficient and cost-effective will optimise programmes driving the development and deployment of new technology.

[23] SQEP - Suitably Qualified and Experienced Person

6 PAST RD&D PROJECTS ON WASTE INVENTORY

The 2022 (Rev 1) iteration of the IAEA Status and Trends publication provides an overview of the current status and trends in spent fuel and radioactive waste management, and includes information on current inventories, expected future waste arisings and strategies for the long-term management of these materials. The information provided in this publication is based primarily on the national profiles submitted by each of the participating Member States, using a common reference date and data presented in the reports to the Sixth Review Meeting of the Contracting Parties to the Joint Convention. The national profiles are provided on the web site accompanying this publication.

Processes for inventory management are typically developed separately, for the reporting and management of Higher Activity Wastes (HAW) and Low Activity Wastes (LAW). These processes are routinely assessed for their adequacy and changed as and when it is appropriate to do so. The most fundamental changes are focussed on the disposition routes available and relate to the safety cases of operating and subsequently closing these disposition routes. The bulk of the inventory information demands are to demonstrate that the RW satisfies the acceptance criteria of these disposition routes.

EURAD Workpackage 12.7[24] produced a comprehensive suite of instructional guidance documents that may be of benefit to radioactive waste management practitioners.

The PREDIS Strategic Research Agenda has shown that inventory development falls into the categories of Strategic Studies and Knowledge Management[25]. Knowledge Management and the provision of the right information at the time it is most needed is a key component of the inventory lifecycle.

7 UNCERTAINTIES

Assessments on the validity of developed inventories have been undertaken for some decades, essentially for as long as radioactive waste has required management. Over the years initiatives and tools have been developed to enable, within a regulated structure, both the inventory development and inventory assessment stages.

The use of statistics[26], tied with characterisation within inventory assessment also has the important benefit of being able to demonstrate the degree of confidence in the derived inventory.

The inventory exists to demonstrate the current waste holdings or potential waste arisings, providing the necessary radiological and non-radiological information to

[24] https://www.ejp-eurad.eu/publications/eurad-d127-contribution-eurad-roadmap-gap-analyses-guidance-and-guide-documents

[25] PRE-DISposal management of Radioactive Waste (PREDIS), Milestone 2.4, Strategic Research Agenda; Version 2. M ay 2023.

[26] Eurachem, CITAC, Eurolab, Nordtest and RSC Analytical Methods Committee, "Measurement uncertainty," Second Edition, 2019.

address all requisite questions at the appropriate time. As such, the level of confidence in the inventory dataset may change according to the phase in the facility lifecycle that the operator finds themselves. Programmes may be required to review characterisation strategies and the incorporation of good practice guidance, where available and appropriate.

The use of statistics within inventory assessment tools can offer a useful mechanism to demonstrate the level of confidence in the inventory. Error bars to certain parameters and values stated with a confidence interval, e.g. 95th percentile underpin the robustness of the data that may otherwise be presented as single point values. Presenting an outcome from such an evaluation can demonstrate confidence in the subsequent decisions made.

Statistical approaches may also support, when embedded into iterative processes such as Data Quality Objectives[27] and the characterisation strategy. More information on this can be found in the Characterisation DI document (2.2.1) and the EURAD Workpackage D10.6 Views of the different actors on uncertainties related to waste inventory [28].

Uncertainty in inventory estimates may be tolerated to a greater degree if the outcome of any decisions remains firm. However, if the inventory bounding has the potential to cause a change in how the waste is to be managed then greater certainty may be required. An example could be to assess whether a waste stream should be managed as short-lived or long-lived ILW and the range of uncertainty covered both options. This may also, in the case of heterogeneous wastes, be considered in terms of segregation into two or more sub-waste streams to allow alternative waste management options to be taken.

The PREDIS SRA identified several issues within RW to be addressed, such as

- The management of non-radiological hazardous wastes
- The solution to, or the prevention of problematic wastes
- The transparency and management plans for future arisings, containing potentially new waste types
- How to record and manage the necessary inventory data

[27] United States Environmental Protection Agency, *Guidance on Systematic Planning Using the Data Quality Objectives Process,* EPA QA/G-4, 2006.

[28] Bielen A., Baksay A., De Gregorio y Robledo S., Plukis A., (2023): UMAN -Views of the different actors on the identification, characterization and potential significance of uncertainties on waste inventory and on the impact of predisposal steps - Final version as of 07.08.2023 of deliverable D10.6 of the HORIZON 2020 project EURAD. EC Grant agreement no: 847593.

8 GUIDANCE, TRAINING AND COMMUNITIES OF PRACTICE

This section provides links to resources, organisations and networks that can help connect people with people, focussed on the domain of inventory.

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Guidance
• Spent Fuel and Radioactive Waste Information System (SRIS) | IAEA. IAEA's website provides information on national spent fuel and radioactive waste management programmes, spent fuel and radioactive waste inventories and facilities, as well as relevant laws and regulations, policies, plans and activities. • UK Radioactive Waste Inventory (UKRWI) (nda.gov.uk) the UKRWI website provides not only details of the UK inventory but provides general information about radioactivity, types of waste and regulations.
Training
• https://www.iaea.org/services/education-and-training/online-learning/spent-fuel-and-radioactive-waste-management-decommissioning-and-environmental-remediation • In the UK, Nuclear Waste Services has developed a broad range of training packages for waste operators. These include training for characterisation and the completion of inventory forms for waste consignments in the UK. These training packages are managed via the use of an online portal, i.e., the NDA Hub.
Active communities of practice and networks
• IAEA – themed mission training – raising the standard across the EU Member States. • In the UK and under the remit of the NDA, National Waste Programmes have set up a number of themed working groups to develop best practice in all aspects of radioactive waste management. Such groups and their output are managed via the use of an online portal, i.e., the NDA Hub.

9 ADDITIONAL REFERENCES AND FUTURE READING

Benchmarking Analysis of Member States Approaches to Definition of National Inventories Radioactive Waste and Spent Fuel. No. ENER/2018/NUCL/SI2.778797, Final report.

NEA - OECD Radioactive Waste Management 2017. National Inventories and Management Strategies for Spent Nuclear Fuel and Radioactive Waste: Extended Methodology for the Common Presentation of Data. NEA No.7371.

SWD (2019) 435 final, COMMISSION STAFF WORKING DOCUMENT: Inventory of radioactive waste and spent fuel present in the Community's territory and the future prospects.

REPORT FROM THE COMMISSION TO THE COUNCIL AND THE EUROPEAN PARLIAMENT on progress of implementation of Council Directive 2011/70/EURATOM and an inventory of radioactive waste and spent fuel present in the Community's territory and the future prospects. {COM(2019) 632 final} - {SWD(2019) 436 final}

Multifactor Optimisation of Predisposal Management of Radioactive Waste; Proceedings of the NEA Joint Workshop 10-14 February 2020; OECD Conference Centre. NEA/RWM/R(2020)3. June 2021.

IAEA Nuclear Energy Series No NW-T-1.14 (Rev. 1). Status and trends in Spent Fuel and Radioactive Waste Management. 2022.