1.4.1 National radioactive waste inventory, Domain Insight

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Overview

This document is part of the suite of domain insight (DI) documents developed by the EURAD project; it provides information on developing and maintaining an inventory of all spent fuel and radioactive wastes, i.e. a national radioactive waste inventory. A high-level overview of the relevant activities are provided at the different phases of the deep geological disposal repository (DGR) programme, as well as relevant background information, international examples and a description of the likely uncertainties.

Keywords

National Inventory, radioactive waste, spent fuel

Key Acronyms

Term	Definition
DGR	Deep geological repository
IAEA	International Atomic Energy Agency
OECD NEA	Organisation for Economic Cooperation and Development Nuclear Energy Agency

1. Typical overall goals and activities in the domain of a National radioactive waste inventory

This domain addresses the development and maintenance of a national inventory of spent fuels and radioactive wastes, hereafter referred to as a National Inventory. For the purposes of this document, it is assumed that the scope of establishing and maintaining a National Inventory includes the collation and management of the data and does not include generating the inventory data for the wastes[1].

Before producing a National Inventory, the key stakeholders should be identified and consulted with to determine their use-cases for the National Inventory. Typical use-cases for a National Inventory include:

- Supporting the development of national policy
  The IAEA's General Safety Requirements (IAEA, 2009) state that national policy

  "has to be based on knowledge of the waste to be managed (e.g. knowledge of the inventory and of waste streams) now and in the future".

- Providing the information needed for international reporting obligations
  Countries are required to report details of their national inventory periodically, for example
  - Signatories to the Joint Convention are required to report to the IAEA ((IAEA, 1997), Article 32).
  - Member states are required to report to the EC ((European Council, 2011), Article 12).
- Providing the information to underpin planning for the management of the radioactive wastes and spent fuel
  Inventory data will be used at all stages of the planning for the management of radioactive waste. For example, the characteristics of the waste will inform how the waste is managed, the quantity of waste deemed to require geological disposal will inform the size and layout of the DGR, the radionuclide and materials inventory will inform the safety assessments, the quantities of certain materials may inform strategic planning or business cases for treatment facilities, etc.
- Supporting stakeholder engagement
  A National Inventory is a valuable tool for communicating inventory information to stakeholders such as government, regulators, waste producers, and local communities. Publicly available details of the National Inventory would further support engagements with communities and consideration should be given to the information that could be published.

The use-cases identified will inform the development of the user requirements that the National Inventory must satisfy to meet the needs of the stakeholders. For example, if the National Inventory is being used to underpin international reporting, a user requirement might be[2]

> *"The user requires the National Inventory to provide sufficient data to allow international reporting obligations to be met."*

Analysis of the requirements will identify the information needs, and therefore the data that need to be collected for the National Inventory. Data quality objectives could be used to identify how accurate the data need to be[3] and these are helpful in guiding those who are producing the data as well as providing a basis for assessing whether the data collected meet the needs of the users.

It is important to periodically review the use-cases, requirements and therefore the data that need to be collected. It is anticipated that the data that need to be collated will evolve: the level of detail that the inventory contains should be appropriate to the stage of the programme and while high-level generic

[1] In preparing the National Inventory, it is important that there is early engagement with those who will be supplying the data to confirm expectations, e.g. the data that needs to be supplied, timescales, etc.

[2] This should be further broken down into each international reporting obligation. Using the examples in the text this would be: "1.1 The user requires the National Inventory to provide sufficient data to allow Joint Convention reporting obligations to be met" and "1.2 The user requires the National Inventory to provide sufficient data to allow EC reporting obligations to be met".

[3] The data quality objectives will be different for each use-case; for example stakeholder engagement activities may require a high-level estimate of the number (and type) of packages, while activities such as the design of the DGR will require more detailed information on the number and type of packages, together with estimates of when they will be consigned to the facility and the uncertainties (e.g. in forecasts of future waste arisings) understood.

information may be appropriate in the earliest stages of the programme, an increasing level of detail will be needed as the programme evolves.

The table below presents typical activities for the National radioactive waste inventory domain. Although the phases below relate to a DGR, a National radioactive waste inventory also supports other management and disposal routes for the radioactive waste such as at surface disposal, near-surface disposal, disposal to appropriately permitted landfill sites, metal treatment, etc. The activities associated with the phases below could equally apply to other disposal facilities and the domain activities would be broadly equivalent (but focused on a different portion of the National Inventory).

Domain Goal	
1.4.1 Develop and maintain an inventory of all spent fuel and radioactive wastes from all sources and activities, together with estimates for future quantities arising, including the characteristics, location, ownership (responsible organisation) and amounts, in accordance with an appropriate classification scheme (National radioactive waste inventory).	
Domain Activities	
Phase 1: Programme Initiation	Agree the National Inventory use-cases with key stakeholders. Analyse the use-cases to produce user requirements for the National Inventory and from these determine the data that need to be collected. Develop an initial National Inventory of radioactive wastes and spent fuels that includes current stocks and forecasts of future arisings; this is likely to involve engagement with the organisations that produce and manage the wastes (e.g. through a centrally co-ordinated data collection exercise). Assumptions may need to be made regarding the forecasts, for example: how long facilities will operate for, how the waste will be conditioned and packaged, etc. Any assumptions should be recorded in an assumptions register. (Alternative inventory scenarios[4] can be used to explore uncertainties in the underpinning assumptions.)
Phase 2: DGR Site Identification	Before updating the National Inventory the inventory use-cases, user requirements and data needs should be reviewed. If additional data needs are identified then work may need to be done to populate the associated data fields. The assumptions that underpin the inventory (and, where they are used, alternative inventory scenarios) should also be reviewed and the assumptions register updated if appropriate. Having agreed the underpinning assumptions, the National Inventory should be updated to reflect the changes. This will include both changes to the assumptions and changes to the data (for example, additional waste may now be in stock and have “actual” data available in waste package records). If the data are generated by external organisations then it will be necessary to review the data (e.g. against data quality objectives); this may be done at a “whole inventory” level or a detailed level, as appropriate. Any areas for improvement should be discussed with the data providers. By this stage, the inventory data should be managed using mature products. The conceptual data models of the NEA’s Repository Metadata project (NEA, 2021) provide some insight into how the data could be structured.
Phase 3: DGR Site Characterisation	The activities carried out in Phase 3 are likely to mirror those that are carried out in Phase 2. By this stage in the programme the inventory production should be following well-established procedures.

[4] An inventory scenario describes how the waste will arise and will include underpinning assumptions such as the duration of operations at existing facilities, or assumptions regarding new facilities. Alternative scenarios are used to explore different future states and allow waste management organisations to explore the impact that changes to certain assumptions would have on their plans.

Phase 4: DGR Construction	The activities carried out in Phase 4 are likely to mirror those that are carried out in Phase 3. However, updates to the National Inventory may not be frequent enough for operating a DGR. For example, short-term forecasts of wastes that will be consigned to the facility will become important and consideration will need to be given to whether these short-term forecasts will be managed alongside or as part of the National Inventory (i.e. will the National Inventory become a "living" dataset with an associated change management process or will the short-term forecasts exist as part of a complementary dataset). Following the start of construction, it may be possible to reduce the data collected as some data may have been required for sites (or host-geologies for disposal facilities) that were not selected. This should be identified in the review of the use-cases, requirements and data needs.
Phase 5: DGR Operation and Closure	At the start of facility construction, the inventory will include details of wastes that already exist and, if necessary, a forecast of wastes that are yet to arise. During operations, it may be necessary to maintain additional detail of the inventory to comply with regulations that are applicable to operational facilities, or to underpin site safety cases; if the National Inventory is to collect these data then this should be identified in the review of use-cases, user requirements and data needs. At facility closure, the inventory of wastes that have been disposed of should be archived for the use of future generations (See DI 7.2.2 Information, Data and Knowledge Management). Note that the National Inventory could be used to record the inventory disposed of in a facility (or facilities); however, it is also possible that separate inventory dataset(s) have been created specifically for this purpose.

2. Contribution to generic safety functions and implementation goals

At the very highest level, the disposal system requirements will include a requirement to safely dispose of the National Inventory (or a sub-set of it: in the case of a DGR the inventory of radioactive wastes and spent fuels for geological disposal). The National Inventory is therefore a fundamental pre-requisite for the planning and development of the disposal system.

2.1 Role of a National radioactive waste inventory in achieving long-term safety of the disposal system

DI 7.1.1 Safety requirements identifies five long-term safety goals (claims):

1. Ensure isolation of the waste from people and the accessible biosphere
2. Provide containment of contaminants
3. Contain contaminants within the total disposal system by retention or retardation
4. Ensure long-term stability with respect to external events and environmental evolution
5. Ensure long-term stability with respect to internal evolution

The degree to which the National Inventory is relied upon to demonstrate the long-term safety goals will vary. Goal 4 (ensuring long-term stability with respect to external events and environmental evolution) is unlikely to require significant inventory data, while other goals (e.g. goal 2: provide containment of contaminants) will require sufficiently accurate inventories. In the case of goal 2 this is likely to consist of an inventory of contaminants and any materials that may enhance or retard the migration of these contaminants as well as details of how the wastes containing these contaminants have been packaged.

To successfully argue that the long-term safety goals will be met it will be necessary to show that the wastes are sufficiently understood[5]. The National Inventory, which will provide input data to simulations and assessments of safety, will therefore form an important part of the claims, arguments and evidence that underpin the long-term safety goals[6].

2.2 Role of a National radioactive waste inventory in achieving feasible implementation of geological disposal

DI 7.1.1 Safety requirements identifies six high-level implementation goals (claims) that support feasible implementation of a DGR:

1. Provide technical practicability
2. Ensure that design conforms to technical design requirements
3. Allow operational flexibility
4. Ensure security and safeguards
5. Satisfy operational safety
6. Reduce environmental impact of operations

As with demonstrating long-term safety, the National Inventory will provide input data to underpin the demonstration of the feasibility of geological disposal. As such, it will be necessary to show that the wastes are sufficiently understood and the National Inventory will form an important part of the claims arguments and evidence that underpin the demonstration of feasible implementation.

3. International examples of a National radioactive waste inventory

Several countries have published detailed inventory reports online; however, only the UK and France maintain websites dedicated to their inventories:

- https://ukinventory.nda.gov.uk/
- https://inventaire.andra.fr/

These websites contain detailed inventory reports as well as the documentation for the supporting sub-components of the inventory (e.g. waste streams) and background information.

In addition to the detailed inventories that individual countries publish, high-level inventory data are available as part of, for example:

- The IAEA's Status and Trends in Spent Fuel and Radioactive Waste Management project; the current version (at the time of publication) is https://www.iaea.org/publications/14739/status-and-trends-in-spent-fuel-and-radioactive-waste-management
- The country profiles available on the IAEA's SRIS (Spent Fuel and Radioactive Waste Information System) website https://www.iaea.org/topics/nuclear-safety-conventions/joint-convention-safety-spent-fuel-management-and-safety-radioactive-waste/documents

[5] One way of doing this would be to have the National Inventory linked to the individual waste package records.
[6] This will also be true for other disposal facilities such as at-surface or near-surface disposal facilities.

4. Critical background information

This section highlights specific components, key information, processes, data or challenges that have a high impact or are considered most critical for the National radioactive waste inventory domain.

Specific components, key information, processes and data

For the purposes of compiling a National Inventory, wastes may be recorded as individual items or grouped into “waste streams” (waste or a group of waste items at a particular site, usually associated with a particular facility or from a particular process or operation). Data are collected for the wastes and, where records exist, these should underpin the National Inventory data.

At various stages in its predisposal management, the radioactive waste needs to be characterised and classified. The National Inventory will need to record the characteristics of the waste that are relevant to its future management; this may include:

- Origin of the waste
  This includes information on when and how the waste arose, where the waste is currently stored and who owns it.
- Waste quantities
  The quantity of waste and when it will arise needs to be recorded in a manner that is useful to the waste management organisation; this could be numbers of packages, waste volumes or waste masses. Each parameter is likely to be useful in different situations and some method of converting between them may be required (e.g. a density and a volume of waste per package).
- Waste characteristics
  Information about the origin of the waste, any processes that it has been subjected to, and its classification. The waste will often be classified according to a national classification scheme. The IAEA has set out a general classification scheme that is based primarily on considerations of long-term safety (IAEA, 2009); however, countries tend to use classification schemes tailored towards the ways in which they manage their radioactive waste.
- Radionuclide data
  There are too many radionuclides to collect data on each one individually and so data are only likely to be collected for those radionuclides that are considered to be significant to safety. The approach to assessing which radionuclides are significant to safety will differ between countries.
- Materials data
  The inventory will need to capture information on any materials that are relevant to safety, for example, any substances that might enhance or retard radionuclide migration in a DGR, materials that are hazardous or polluting, etc.
- Treatment and packaging
  It will be important to record information about how the waste has been (or is forecast to be) treated and packaged; this may include the package used, the conditioning material(s), the void space in the completed packages, etc.
- Underpinning and uncertainties
  The underpinning for the National Inventory data should be recorded and where data are uncertain it may be useful to collect information on the uncertainties, either qualitatively (e.g. are the data best estimate, bounding, etc.) or quantitatively (e.g., provision of numerical multipliers for upper and lower bounds on the parameter).

Radioactivity data will be an important component of a National Inventory and the ability to calculate the activity, or decay heat, etc. at later dates will be needed; this will be underpinned by nuclear data. Various nuclear data libraries are available and a selection can be browsed using the online JANIS tool (OECD NEA, 2023).

Challenges

Challenges that can arise in the production and maintenance of a National Inventory include

- Quantity of inventory data to manage
  A National Inventory is likely to contain a significant quantity of data and this needs to be managed appropriately. Depending upon the size of the programme and the quantity of data, this may require dedicated tool(s) to be developed and maintained. Such challenges can

generally be overcome through early planning so that the necessary tools are available when they are needed. If a range of inventory data management tools are in use then there may be additional challenges in collection and transfer of the data between organisations.

- Inventory data collection
  If wastes are generated by multiple different organisations, and the data collected and maintained by each organisation for the purposes of managing their site do not align with the data collected for the National Inventory, then additional effort may be needed to ensure the completeness of the dataset. This may be particularly relevant where additional data requirements are driven by new use-cases or where the data are needed solely for the disposal of the waste. In these cases, early engagement is important and the traceability of the data to requirements helps to show why it is necessary for the waste producing organisation to provide the data.
  The security classification of data can also pose challenges to the collection or transfer of data. Early engagement with the organisations who own the data is important and the ability to demonstrate why the data are required (i.e. traceability to requirements, as discussed in section 1) will support the case for data transfer.
  For some older facilities, data may have been stored on systems that are no longer supported, posing challenges to data extraction. In these cases, it is important to identify the need for the data early so that plans can be made for the data extraction.
- Quantifying uncertainties reported in the inventory
  This is particularly pertinent for older wastes where records may not be readily available or for wastes that have not yet been characterised. In such cases it is important that the uncertainties are understood so that the impact on the inventory can be assessed (e.g. via alternative inventory scenarios or recording of uncertainties).
  DGR programmes can span 100 years or more. Where the wastes are not forecast to arise for many decades there is likely to be greater uncertainty associated with the inventory data. To allow programmes to progress, this uncertainty needs to be quantified; this could be as a simple multiplier to be applied to the best estimate data (e.g. where it is known waste will arise from a facility but it is not known how much, such as would be the case where the operational lifetime of a facility was not known), or through the use of inventory scenarios to develop different future inventories.

4.1 Integrated information, data or knowledge (from other domains) that impacts understanding of a National radioactive waste inventory

The National Inventory of radioactive wastes is an important input to many aspects of radioactive waste management. In particular

- The quantities and types of wastes that will arise, and when they arise will inform the development of National Policy (Domain 1.1.1).
- The data within the National Inventory will be an important input to designing and developing a disposal system (Sub-Theme 5.1) as well as the safety assessments (Sub-Theme 7.3).

The maintenance of the National Inventory will continue throughout the design and development of the DGR and the characterisation of wastes (Domain 2.2.1) and any records produced as part of the Quality and Management Systems (Domain 2.3.1) will provide an important input to the National Inventory.

Finally, the inventory of wastes that has been disposed of will need to be archived and there is an important interface with the Information, Data and Knowledge Management Domain (Domain 7.2.2).

5. Maturity of knowledge and technology

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

For countries involved in early nuclear research, technical records of radioactive waste production, accumulations and off-site disposals would have been maintained locally at sites for operational

purposes. The development of National Inventories, with a consistent set of assumptions for nuclear programmes would have followed later and has been ongoing for several decades (certainly dating back to the early 1980s), although this will vary from country to country. The production of National Inventories is therefore a relatively mature area. However,

- the technologies used for inventory data collection and management will vary between countries, with the size and complexity of the inventory influencing the systems that are used. The use of a single system across a country would help to ensure consistency of data and having checks of the data in the system would help to improve the quality assurance of the data. If bespoke software is being used this will need to be maintained (or possibly refreshed) to ensure it adheres to modern standards.
- knowledge of the inventory of wastes in stock will improve with time but changes to the underpinning assumptions could significantly alter the forecasts of wastes to arise.
- maintenance of a National Inventory is an iterative process: if it is found that additional information needs to be collected, this can be added to the scope of the inventory[7]; however, this may pose challenges for wastes that have already been generated and / or packaged if the information has not already been recorded. In such cases the maturity of the data is likely to be better for more recent wastes.

5.1 Past and ongoing (RD&D) projects

Because there are a range of different waste classification systems in use across different countries, and because each country's projections of future arisings of wastes are not to the same date, comparison of National Inventories is not straightforward. The Expert Group on Waste Inventorying and Reporting Methodology was set up with the goal of developing a common presenting format for national inventory data. This project has now completed and the outputs of the group's work can be found online:

- https://www.oecd-nea.org/rwm/egirm/

The Status and Trends in Spent Fuel and Radioactive Waste Management project is ongoing and features information on the inventories in different countries. The latest report (at the time of publication) is available online:

- https://www.iaea.org/topics/nuclear-safety-conventions/joint-convention-safety-spent-fuel-management-and-safety-radioactive-waste/documents

6. Uncertainties

National Inventories will contain several sources of uncertainties, such as:

- The assumptions that underpin the inventory, for example assumptions relating to
  - how long waste-generating facilities will operate for and therefore how much waste they will generate.
  - the way in which waste may be treated (and considerations of any secondary waste products that may be generated).
  - the way in which the waste is assumed to be encapsulated and packaged, which may change as a result of ongoing or future research.
- The characterisation of wastes, for example
  - Uncertainties in the quantities of waste (particularly relevant to future arisings, but also applicable to current stocks of wastes).
  - Uncertainties in the measured activities of radionuclides (for more information see Domain 2.2.1 Characterisation).
  - Uncertainties in the calculations that underpin the assigned waste radionuclide activities, for example:
    - The initial composition of an irradiated material will influence its radionuclide inventory. The initial content of the materials will be subject to uncertainties, particularly where the element of interest is an impurity.

[7] Through review of the use-cases, user requirements and data needs, as outlined in section 1.

- There will be uncertainties introduced in any reactor physics calculations; these could be a result of uncertainties in the input parameters, the discretization used in modelling, imperfect representation of the irradiation history of the materials, etc.

7. Further reading, external links and references

7.1 External links

- https://ukinventory.nda.gov.uk/
- https://inventaire.andra.fr/
- https://www.oecd-nea.org/rwm/egirm/
- https://www.iaea.org/topics/nuclear-safety-conventions/joint-convention-safety-spent-fuel-management-and-safety-radioactive-waste/documents

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