Metadata in Geological Disposal of Radioactive Waste: The RepMet Libraries

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Abstract

The OECD Nuclear Energy Agency (NEA) launched the Radioactive Waste Repository Metadata Management initiative (RepMet) in 2014 under the auspices of the Integration Group for the Safety Case (IGSC) technical advisory body. The initiative involves programmes from over ten different countries working on the formulation of a consistent set of guiding principles for capturing and generating metadata, recommending a shortlist of selected relevant standards and guidelines on international good practices. One of the main objectives of RepMet is to provide descriptions of conceptual data models and controlled vocabularies, forming the so-called "libraries" in the project context, which support data and metadata use for relevant topics within radioactive waste repository programmes. RepMet has developed a Site Characterisation Library, a Waste Package Library, and a Repository Library. This paper describes the three libraries and discusses their relationship to the overall RepMet initiative.

1. RepMet Introduction

The Radioactive Waste Repository Metadata Management (RepMet) is an initiative under the Integration Group for the Safety Case (IGSC) of the NEA Radioactive Waste Management Committee (RWMC).

The IGSC launched the RepMet initiative in 2014 to investigate the metadata, a key tool of modern data management, in order to bring about a better understanding of their application within the national programmes for the realisation of the radioactive waste repositories. Several worldwide Radioactive Waste Management Organisations (RWMOs) and research laboratories from NEA countries were involved in the RepMet initiative: Andra (France), Enresa (Spain), JAEA (Japan), Nagra (Switzerland), NDA (United Kingdom), NWMO (Canada), ONDRAF/NIRAS (Belgium), Posiva (Finland), PURAM (Hungary), Sandia National Laboratories (United States), SKB (Sweden), SÚRAO (Czech Republic).

RepMet developed conceptual designs of *data and metadata libraries* in the three disciplines shown in Table 1.

Table 1: Disciplines and topics of the RepMet data and metadata libraries

Disciplines	RepMet Libraries	Topics
Radioactive Waste Management	Waste Package Library	Packaged waste and spent nuclear fuel ready for final disposal at the repository
Geoscience	Site Characterisation Library	Geological and geophysical characterisation of the repository site
Engineering	Repository Design Library	Repository requirements and structures at closure

RepMet investigated metadata to foster a better understanding of their application within RWMOs in support of national programmes. Within this framework, the main RepMet objectives are:

- the formulation of a consistent and sufficient set of guiding principles for capturing and generating metadata (policy guidance)
- the identification of metadata sets that can be used by national programmes to manage their repository data, information and record, harmonised internationally.

2. Metadata

National programmes for radioactive waste repositories are collecting large amounts of data that have to be managed throughout the entire period of institutionalised oversight, spanning a considerable length of time. The data, metadata, and related records also increase in number, type, and quality as programmes proceed through the successive stages of repository development: pre-siting, siting, site characterisation, construction, operations, pre-closure and finally closure. Regulatory and societal approvals are included in this sequence. Current programmes are also documenting past repository programmes, so that current and future generations are able to understand actions carried out in the past, by retrospectively adding metadata to help organise and arrange programme records.

The available data, information and records are accessed and updated according to management systems, with the underlying repository allowing users to locate what they require through searches of full text or the associated metadata.

Metadata allows context to be stored with data and provide additional information so that it can be located, used and reused. It can also be a useful tool to help a waste management organisation to demonstrate that their programmes are appropriately driven. Such context setting information may include information on quality checking or approval; provenance or ownership.

When considering metadata for a particular domain (as for RepMet), metadata are typically associated with a set of predefined digital or physical objects, for example an ID for a waste package or signing date of a quality log. It is important to remember, however, that metadata also cover how these elements are to be constructed and related to one another (for example how a waste package relates to a packaging campaign), the type and range of values they may take (for example, a package weight must be greater than 0 kg).

3. RepMet Scope

The scope of the RepMet initiative includes the following:

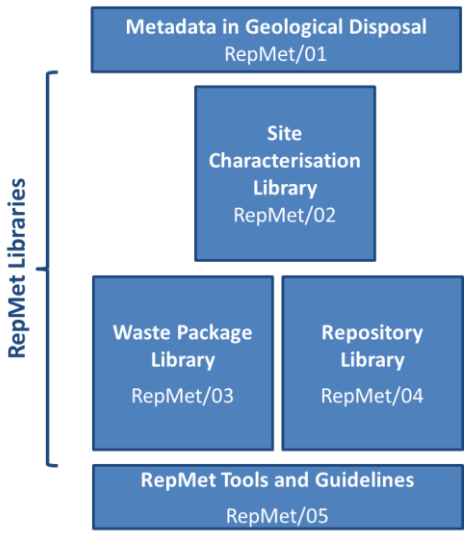
- Identification of methods and procedures for the gathering and management of data and metadata.
- Justification of the sufficiency of the set of metadata describing the identified data to support use and re-use.
- Relationship to safety assessment. The metadata required for information captured “in the field” will differ from that required for analysed and derived data that are often used within safety assessment models. (Safety assessment models are to be discussed in detail in future work.)
- Identification of methods and principles to guarantee the persistence in time of the above procedures.
- Guidelines for metadata management.
- Controlled dictionaries and policy as a means of ensuring consistency and reliability of data and cataloguing.
- Use of metadata to support data auditability, verification methods and, if needed, modification.
- Provision of a basis for the exchange and sharing of data between organisations, stakeholders and member nations, which may be separated cross generations.
- Identification of methods and procedures for the data and metadata gathering and management.

RepMet does not intend to promote any commercial products or services for managing metadata.

4. RepMet Deliverables

Figure 1 illustrates the structure of the RepMet initiative deliverables that were produced during the initiative from its launch in 2014 to 2017.

Figure 1: RepMet Deliverables



The first document of the deliverables deals with the application of metadata in the field of radioactive

waste geological disposal from a general, high-level point of view:

- RepMet/01 – "Metadata in Geological Disposal" provides an overview and brief summary of RepMet goals, deliverables, various aspects of metadata implementation and issues for consideration.

The following three deliverable documents, the so-called "Libraries", adopted a more technical point of view. They discuss the key aspects of data and related metadata for selected topics of different scientific and technical disciplines involved in the realisation of a radioactive waste repository. The Libraries include conceptual data models (CDMs), descriptions of data entities, attributes, associated metadata and other relevant information:

- RepMet/02 – "Site Characterisation Library" deals with data and related metadata that are considered during the selection of the characterisation of a site investigated and surveyed for suitability for radioactive waste disposal purposes leading up to site selection;
- RepMet/03 – "Waste Package Library" deals with data and related metadata about packaged waste and spent nuclear fuel that, after proper treatment and conditioning processes, are ready for final disposal at the repository;
- RepMet/04 – "Repository Library" deals with data and related metadata which relate to the engineered structures and waste acceptance requirements of the radioactive waste repositories.

The above Libraries can be used independently of each other, however utilising all of the libraries and the approach outlined in these documents provides the additional benefit of having a uniform approach to data and metadata management.

A fifth document includes common techniques and tools that RepMet has adopted for the development of multiple libraries and which are deemed useful for relevant RWMO activities and initiatives:

- RepMet/05 – RepMet Tools & Guidelines supports the libraries providing a number of useful tools, methods, metadata standards, guidelines, and approaches that were either used in developing the Libraries or are useful for the RWMO when adopting and implementing the Libraries.

RepMet will close its activities in 2017. The above deliverable documents will be made available publicly in electronic form on the RepMet webpage[1] on the NEA website in the next months. We now discuss and present the three RepMet libraries in more detail.

5. RepMet Libraries

The RepMet Libraries provide the conceptual design of databases about the topics of interest reported in Table 1. They report the CDMs[2] of the databases, i.e. the organisation and the structure of the databases in terms of objects of interest (i.e. entities) together with their descriptive characteristics (i.e. attributes) and the logical associations among them (i.e. relationships). It is out of the RepMet scope to identify the software and hardware technology for the realisation of such databases.

The main feature of the RepMet Libraries is the implementation in the database's conceptual design of metadata sets to support the long-term management of the information built on the data associated with the entities and the attributes in the library. These metadata:

- indicate the source of the data: who?, what?, when?, where?, why? and how?;
- provide context to facilitate the accurate interpretation and use of data;
- describe data quality (e.g. uncertainty);
- add additional information about the data in a structured and detailed way;
- help users quickly find the data object that they are looking for; and
- support the search for information (e.g. promote scientific research, engineering, safety assessment).

5.1. Site Characterisation Library

Site characterisation requires knowledge about rock stability and isolation properties that are controlled by surface and underground conditions close to the repository and in the wider environment. A complex model of the geological environment including information on composition, structure and processes are needed. This knowledge is improved by using geoscience, a wide discipline that includes many scientific areas, like traditional geology, geophysics, hydrogeology, geochemistry, satellite imagery, etc. It is not enough to collect data once. It is essential to do monitoring, i.e. repeating observations on a regular basis.

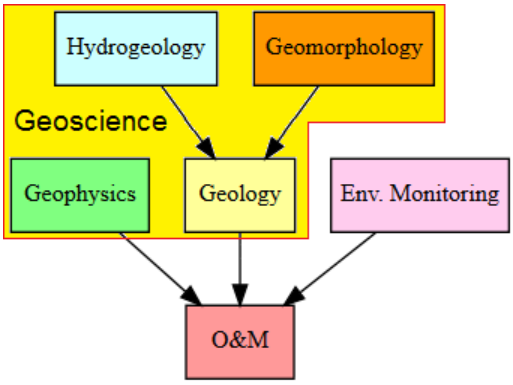
All this involves handling large amount of data with heterogeneous structure and content. Heterogeneity may arise for methodological,

1. www.oecd-nea.org/rwm/igsc/repmet.

2. The CDMs cannot be shown in this document as a result of their size, but will be displayed and discussed during the presentation, and can be seen in the RepMet libraries themselves.

historical and/or practical reasons. In the last decade, considerable effort has been devoted to harmonising data related to knowledge about the natural and artificial environment. One of the biggest initiatives in Europe is the INSPIRE (Internet Spatial Infrastructure for Europe) directive that integrates 34 environmental themes into one uniform CDM. It is based on a long list of open standards and harmonised web services. The proposed CDM for the RepMet Geoscience Library is largely based on the INSPIRE principles and data models.

Figure 2. Geoscience domains as defined in EU INSPIRE Directive



There are six schemas in the INSPIRE data model that are most relevant to Site Characterisation. Figure 2 shows the scientific domains and their relations as they are represented in the existing standard. These are:

- Geology
- Hydrogeology
- Geomorphology
- Geophysics
- Environmental Monitoring; and
- Sampling

Geology, Hydrogeology, Geomorphology and Geophysics belong together in the Geology spatial data theme of INSPIRE. Environmental Monitoring is defined in a separate theme. Monitoring facilities often collect information about geological and geophysical phenomena as well. The common building block is the Observation and Measurements (O&M) standard that creates an important bridge between seemingly separate domains. The O&M concept allows geosciences and environmental monitoring to be integrated into one generic CDM that RepMet adopted to cover the geoscientific aspects of site characterisation relevant to nuclear waste disposal facilities. Hierarchical dictionaries of physical property and observation process names are part of the INSPIRE framework and are used as attributes for the RepMet Site Characterisation Library CDM.

5.2 Waste Package Library

The RepMet group developed the Waste Package Library with the purpose of presenting sets of data and metadata that national programmes may use for the data, information and records management, specifically with respect to the waste packages ready for disposal at the final repository. Low Level Waste (LLW), Intermediate Level Waste (ILW), High Level Waste (HLW) and Spent Nuclear Fuel (SNF) from commercial light water reactors (LWRs) are all considered.

The CDM for packaged radioactive waste and SNF is an original RepMet product and it is based on eleven entities. These entities, together with their definitions, draw on definitions from the IAEA (2006). However, a number have been modified in order to ensure consistency within the data model that has been developed, and add flexibility to the CDM, thereby allowing it to meet the needs of the diverse range of packaging solutions adopted by WMOs worldwide.

The entities and their definitions are listed below:

1. *Buffer* – additional material or a mix of materials that contribute to preventing or reducing the migration of radionuclides from the disposal module.
2. *Disposal container* – container into which one or more waste packages, and optional filler or buffer, may be placed.
3. *Disposal module* – ensemble of one or more waste packages together with their disposal container, optional filler(s) and buffer, suitable for handling, transport, storage and disposal.
4. *Filler* – material or a mix of materials that is added to the disposal container filling the void spaces.
5. *Overpack* – container into which the wasteform container may be placed.
6. *Stabiliser* – material or mix of materials that is used in treatment and conditioning processes to stabilise, either physically and/or chemically, one or more wastes, or one or more spent nuclear fuel, to give a wasteform.
7. *Spent nuclear fuel* – nuclear fuel removed from a reactor following irradiation that is no longer usable in its present form.
8. *Waste* – raw material in gaseous, liquid or solid form that is intended for storage and disposal after proper treatment and conditioning. Waste materials conditioned into containers that are considered unfit[3] for disposal are also waste, as they require further treatment before disposal.

3. E.g. legacy waste packages that cannot be disposed of according to the current policies and practices; drums to be supercompacted and then inserted in a bigger container for volume reduction.

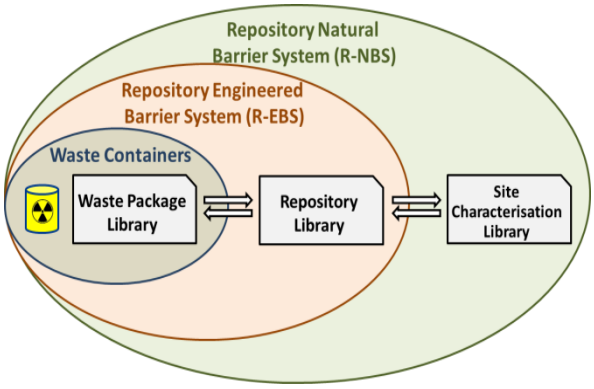
9. *Waste package* – ensemble of one or more wasteforms together with their wasteform container and optional overpack(s), suitable for handling, transport, storage and/or disposal.
10. *Wasteform* – waste, or the spent nuclear fuel, in the physically and chemically stable form in which it will be disposed of, including any stabilisers and container furniture [4], but not including the wasteform container.
11. *Wasteform container* – container into which one or more wasteforms are made or placed.

The attributes of the Waste Package Library are structured and arranged in the form of an original controlled dictionary according to the RDF/SKOS format. It is included in the library final report.

5.3. Repository Library

The purpose of the repository library is to present sets of metadata that can be used by national programmes for information and records management, specifically with respect to radioactive waste repositories. Repositories for LLW, ILW, HLW and commercial LWR SNF are all considered, and this document is intended to be a registry on RWM repository subjects of common interest based on the practices currently in use internationally. The content of this library has been developed from the exchange of experience among project members, and discussions with external experts and constituencies.

Figure 3. Multiple Barriers of a Repository



A RWM repository's primary objective is to ensure that radioactive and chemical releases to the environment are mitigated to levels at or below the cognizant regulatory requirements. A repository may accomplish this through a combination of engineered and natural barriers that contribute to the containment, retardation and/or isolation of (radioactive or chemical) contaminants present in the waste.

Figure 3 provides a graphical representation of multiple barriers in a repository contributing to the containment of radioactive and/or chemical contaminants present in the waste. Beginning with the *Waste Containers*, including such elements as disposal modules, overpack or other physical barriers included with the waste package, the waste package is designed to contain the contents during storage, transportation and emplacement in a repository. *Repository Engineered Barrier Systems* (EBS) may be added around or near the waste package emplaced in the repository to further contain radioactive and/or chemical contaminants in the area near the waste package. *Repository Natural Barrier Systems* may be considered and used by the repository host rock media to ensure additional containment of radionuclide or chemical contaminates that may have breached a waste package and the EBS.

For the RepMet CDM of a radioactive waste repository, six entities have been identified. These entity selections were developed for a repository at the time of closure, based on the assumption that the metadata requirements will be known in totality (maturity) at this time. They are based on the experience of subject matter experts involved in RepMet as well as a review of selected reports on the development of radioactive waste repositories.

The entities and their definitions are listed below:

1. *Facility information* – a nuclear facility where waste is placed for disposal:
   - Geological repository – A facility for radioactive waste disposal located underground (usually several hundred metres or more below the surface) in a stable geological formation to provide long-term isolation of radionuclides from the biosphere.
   - Near surface repository – A facility for radioactive waste disposal located at or within a few tens of metres of the Earth's surface.
2. *Repository engineered barrier system (R-EBS)* – manufactured physical obstruction that contributes to the containment, retardation and/or isolation of (radioactive or chemical) contaminants present in the waste that is part of the repository facility or is created by/in the repository facility.
3. *Repository natural barrier system (R-NBS)* – naturally occurring physical obstruction that contributes to the containment, retardation and/or isolation of (radioactive or chemical) contaminants present in the waste. Data for this entity comes from the RepMet Site Characterisation Library.
4. *Repository monitoring system* – systems and processes implemented in the repository to monitor any aspect of repository performance, including radionuclide release, chemical release and/or heat release to the near field, far field and the biosphere.

4. E.g. dewatering tubes, in-drum mixing puddles.

5. *Waste acceptance criteria (WAC)* – quantitative or qualitative criteria specified by the regulatory body, or specified by an operator and approved by the regulatory body, for radioactive waste to be accepted by the operator of a repository for disposal, or by the operator of a storage facility for storage. Waste acceptance criteria might include, for example, restrictions on the activity concentration or the total activity of particular radionuclides (or types of radionuclide) in the waste or requirements concerning the waste form or waste package.
6. *Waste package emplacement* - describes the way waste packages are placed in the repository for final disposal. Such placement may include vertical or horizontal placement in drifts, or placement in boreholes (for example). Much of the data for this entity is derived from the RepMet Waste Package Library.

Similar to the Waste Package Library, the attributes of the Repository Library are structured and arranged in the form of an original controlled dictionary according to the RDF/SKOS format. It is included in the library final report.

6. Closing Remarks

Metadata enables RWMOs to manage their data in a well-organised manner, meeting statutory requirements and ensuring that data quality is not eroded, confidence in the stored data is maintained, that it remains suitable for support of their future decisions and operations efforts and meets the requirements of their designated communities now and in the future.

RepMet has formulated a consistent set of guiding principles for metadata management in the context of geological repositories; the results of the work are useful to operators, regulators and other relevant actors. The Libraries and associated documents have been prepared with the intent to provide generic models, processes and descriptions that can be tailored to the needs of virtually any RWMO. These can be regarded as a common basis for the development of metadata.

RepMet recognises that each RWMO's activities are in many respects unique, and that each radioactive waste site has characteristics that are exclusive to that particular site. However, there are also many common and general aspects of radioactive waste management and final disposal.

Each RWMO needs to adapt the provided models, processes and descriptions to ensure that the adapted constituents meet the requirements of local regulations, the RWMO's individual needs, and the individual characteristics and the applied technology of the individual radioactive waste management operations.

While RepMet has completed key deliverables in its initial phase, the group recognises the following outstanding work:

- Development of a complete metadata structure/database for a safety assessment tailor-made for the needs of the nuclear waste industry. Extension of the use of the developed metadata structure developed by RepMet to encompass also the data related to the safety case and its "models" (abstract, geometric, stochastic, deterministic).
- Creation of new RepMet Libraries including different topics for waste management pre-closure, e.g. "waste treatment and conditioning", "plant operations", "interim storage of the waste package".
- Extension of the current RepMet Libraries (e.g. maturing, increasing the level of detail).
- Application of the O&M standard that RepMet has adopted to support safety assessment process chains and for the development of the safety case (e.g. new and dedicated RDF/SKOS controlled dictionaries and models).
- Definition of RDF/SKOS controlled dictionaries for the IGSC FEP Task Group.
- Definition of conceptual requirements for the creation of a central metadata database to allow data from multiple databases (e.g. commercial off the shelf [COTS] offerings) to be extracted and combined from a single query. These requirements should take into account the possible conflicts of interest when handling metadata.
- Formulation of data dictionaries for RWMO modelling.

7. Disclosure

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The opinions expressed and arguments employed herein are those of the authors and do not necessarily reflect the official views of the OECD, the NEA or of the governments of their member countries.

8. References

International Atomic Energy Agency (IAEA) (2006), *Development of Specifications for Radioactive Waste Packages*, Vienna, Austria, IAEA-TECDOC-1515.

Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an

Infrastructure for Spatial Information in the European Community (INSPIRE), European Union, 25 April 2007, *Official Journal of the European Union*.

OGC (Open Geospatial Consortium), Geographic information – Metadata. [Online] www.iso.org/obp/ui/#iso:std:iso:19115:ed-1:v1:en.

World Wide Web Consortium, SKOS Simple Knowledge Organization System Primer, [Online] www.w3.org/TR/skos-primer.