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Repository Library

A Report of the Radioactive Waste Repository Metadata Management (RepMet) Initiative

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Radioactive Waste Management Committee

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Executive summary

The Radioactive Waste Repository Metadata Management (RepMet) initiative was launched in 2014 by the Integration Group for the Safety Case (IGSC) of the OECD Nuclear Energy Agency (NEA) Radioactive Waste Management Committee (RWMC). RepMet analysed and investigated the application of metadata, a fundamental tool of modern data and information management, within national programmes for radioactive waste repositories. This analysis concluded that there is a great need and potential for metadata management and harmonisation.

Metadata enables Radioactive Waste Management Organisations (RWMOs) to manage their data and information in a structured manner. This supports them in meeting statutory requirements and ensuring that data quality and confidence in the stored data is maintained, and that data remain suitable for the support of future management and operational activities, and for meeting the requirements of their designated communities now and in the future.

A special characteristic of radioactive waste repositories is the long time between construction and closure of the facility – typically periods in excess of one hundred years. This means that systems handling data and relevant supporting information (metadata) will, in all likelihood, go through technological and other changes; data media and the data themselves may become unreadable; and programmes handling such data may become obsolete. In addition, successive generations of workers will perform tasks on the site during this period with a high probability that not all knowledge will be handed down through the generations. Therefore, the data handling operations must enable the long-term, intergenerational reliability and usability of data.

Given this challenge, the main aim of RepMet has been to formulate a consistent set of guiding principles for capturing and generating metadata, in order to enable national programmes to create sets of metadata that can be used to manage their repository data, information and records in a way that is both harmonised internationally and suitable for long-term management and utilisation in safety cases and elsewhere.

RepMet has produced five interrelated reports that discuss the key aspects of data and related metadata for selected scientific and technical topics involved in the life cycle of a radioactive waste repository. These reports include, and are underpinned by, three technical libraries containing high-level conceptual data models (CDMs), descriptions of data entities, attributes, associated metadata and controlled dictionaries. The libraries can be used independently of each other; however, utilising all of the libraries and the approach outlined in these documents helps provide the additional benefit of a uniform approach to metadata management.

This document, the Repository Library, is the fourth of these five reports. It supports an associated technical library dealing with data and related metadata about requirements and structures of a radioactive waste repository at the time of closure. The library can be used by national programmes for information and records management, specifically with respect to radioactive waste repositories for LLW, ILW, HLW and commercial spent nuclear fuel.

This library focuses mainly on data and metadata that relate to the engineered structures and waste acceptance requirements of a radioactive waste repository.

The Repository Library has two principal aims:

- to show how the use of appropriate metadata can support the long-term management of the "core information", that is acquired during the management and operation of a radioactive waste repository at the time of closure;
- to provide application examples about how implementing the metadata-based techniques can support the long-term management of the "core information".

Several worldwide RWMOs and research laboratories from OECD 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) and SÚRAO (Czech Republic).

It is hoped that RepMet activities will contribute to the easing of the data management burden on individual RWMOs and will be a move towards interoperability and harmonisation. A joint set of principles, controlled dictionaries, data model libraries, etc. can facilitate data exchange with common stakeholders such as international peer review groups, NGOs and regulators. This approach should allow less mature programmes to benefit from the advances made by other sister organisations. Adoption of RepMet's CDMs can contribute to improving the quality and cost-effectiveness of an RWMO's data and metadata management activities.

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

List of abbreviations and acronyms

AIC	Active institutional control
Andra	Agence nationale pour la gestion des déchets radioactifs (National Radioactive Waste Management Agency, France)
BIM	Building Information Modelling
CDM	Conceptual data model
CH-TRU	Contact handled transuranic waste
DOE	United States Department of Energy
EBS	Engineered Barrier System
Enresa	Empresa Nacional de Residuos Radioactivos SA (National Radioactive Waste Company, Spain)
EPA	United States Environmental Protection Agency
ERDs	Entity Relationship Diagrams
FEPs	Features, Events and Processes
HLW	High-level radioactive waste
IAEA	International Atomic Energy Agency
IFEP	Nuclear Energy Agency International Features, Event and Processes
IGSC	Integration Group for the Safety Case
ILW	Intermediate-level radioactive waste
ISO	International Organization for Standardization
JAEA	Japan Atomic Energy Agency (Japan)
LILW	Low and intermediate-level radioactive waste
LLW	Low-level radioactive waste
MRMS	Minnesota Recordkeeping Metadata Standard
Nagra	National Cooperative for the Disposal of Radioactive Waste (Switzerland)
NDA	Nuclear Decommissioning Authority (United Kingdom)
NEA	Nuclear Energy Agency
NPP	Nuclear Power Plant
NRC	United States Nuclear Regulatory Commission
NRWR	National Radioactive Waste Repository

NUMO	Nuclear Waste Management Organisation (Japan)
OECD	Organisation for Economic Co-operation and Development
OGC	Open Geospatial Consortium
O&M	Observations and measurements
ONDRAF/NIRAS	National Agency for Radioactive Waste and Enriched Fissile Material (Belgium)
Posiva	Expert organisation in nuclear waste management (Finland)
PURAM	Public Limited Company for Radioactive Waste Management (Hungary)
RDF	Resource Description Framework
RepMet	Radioactive Waste Repository Metadata Management (NEA)
R-EBS	Repository Engineered Barrier System
R-NBS	Repository Natural Barrier System
RH-TRU	Remote handled transuranic waste
RWM	Radioactive waste management
RWM/NDA	Radioactive Waste Management Ltd. / Nuclear Decommissioning Authority (United Kingdom)
RWMC	Radioactive Waste Management Committee (NEA)
RMWO	Radioactive Waste Management Organisation
SKB	Nuclear Fuel and Waste Management Company (Sweden)
SKOS	Simple Knowledge Organization System
SÚRAO	Radioactive Waste Repository Authority (Czech Republic)
TRU	Transuranic
TSPA	Total System Performance Assessment
URL	Universal Resource Locator
VLLW	Very Low-Level Waste
WAC	Waste Acceptance Criteria
W3C	World Wide Web Consortium
WP	Waste Package
WIPP	Waste Isolation Pilot Plant

1. Introduction

1.1. The aim of the RepMet initiative

In order to support their operational, pre- or post-closure safety cases and other requirements, Radioactive Waste Management Organisations (RWMOs) have to manage very large amounts of data that they both produce and receive. A special characteristic of radioactive waste repositories is the long time between construction and closure of the facility – typically periods in excess of one hundred years. This means that systems handling data and relevant supporting information (metadata) will, in all likelihood, go through technological and other changes; data media and the data themselves may become unreadable; and programmes handling such data may become obsolete. In addition, successive generations of workers will perform tasks on the site during this period with a high probability that not all knowledge will be handed down through the generations. Therefore, the data handling operations of RWMOs must enable the long-term, intergenerational reliability and usability of data.

Given this challenge, the main aim of Radioactive Waste Repository Metadata Management (RepMet) has been to formulate a consistent set of guiding principles for capturing and generating metadata, in order to enable national programmes to create sets of metadata that can be used to manage their repository data, information and records in a way that is both harmonised internationally and suitable for long-term management and utilisation in safety cases and elsewhere.

Box 1.1: What is RepMet?

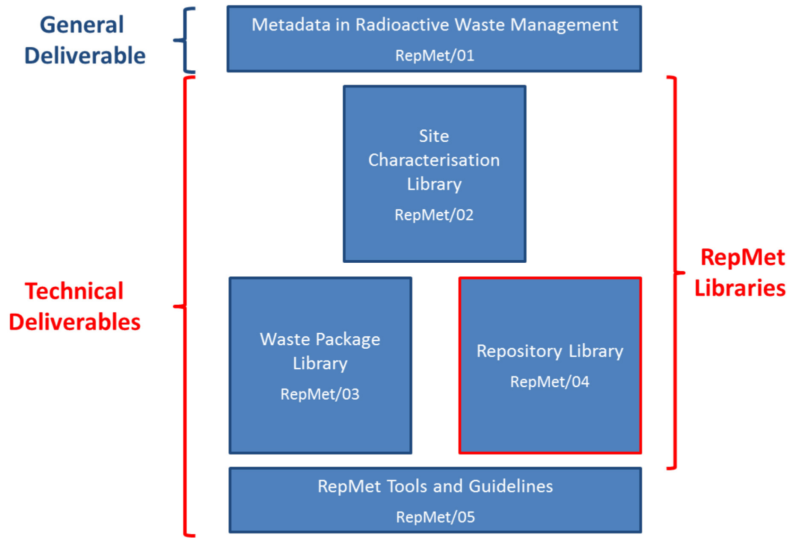
The Radioactive Waste Repository Metadata Management (RepMet) initiative was launched in 2014 by the Integration Group for the Safety Case (IGSC) of the Radioactive Waste Management Committee (RWMC) at the Nuclear Energy Agency (NEA). RepMet analysed and investigated the application of metadata, a fundamental tool of modern data and information management, within national programmes for radioactive waste repositories. Based on this analysis it was realised that there is a great need and potential for metadata management and harmonisation.

Several worldwide RWMOs and research laboratories from OECD NEA countries were involved in the RepMet initiative: Andra (France), Enresa (Spain), JAEA (Japan), Nagra (Switzerland), NWMO (Canada), ONDRAF/NIRAS (Belgium), Posiva (Finland), PURAM (Hungary), RWM/NDA (United Kingdom), Sandia National Laboratories (United States), SKB (Sweden) and SÚRAO (Czech Republic).

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

1.2. The products of the RepMet initiative and their intended audiences

Figure 1.1: The RepMet Document Family



Source: NEA, 2019.

RepMet has produced five key interrelated documents, summarised in Figure 1.1.

The information provided within these documents is primarily aimed at RWMOs that are considering developing information systems or establishing knowledge management practices related to geological disposal, or that are planning to renew or update their existing data management practices. This information is intended to be sufficiently generic to enable it to be adapted by almost any RWMO. The information may also be of use for other disciplines such as those related to developing inventory and decommissioning models.

The five documents[1] are as follows:

RepMet/01 – *Metadata for Radioactive Waste Management* (NEA, 2018) provides an overview of metadata and its application within RWMOs, discusses issues around the implementation of metadata, and outlines the outputs of RepMet and how they may be used. It also provides specific recommendations concerning metadata for RWMOs.

The three reports identified as "RepMet Libraries" are more technically detailed. They discuss the key aspects of data and related metadata for selected scientific and technical topics involved in the life cycle of a radioactive waste repository. These reports include, and are underpinned by, three technical libraries, containing high-level conceptual data models, descriptions of data entities, attributes, associated metadata and other relevant information, and are ready to support the activities of RWMOs. The libraries can be used independently of each other; however, utilising all of the libraries and the approach outlined

1. The documents are available in electronic form on the RepMet webpage of the NEA website. See www.oecd-nea.org/jcms/pl_61001.

in these documents helps provide the additional benefit of a uniform approach to metadata management.

RepMet/02 – "Site Characterisation Library" (NEA, 2021a) deals with data and related metadata that are considered during 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" (NEA, 2021b) 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" (this document) deals with data and related metadata relating to the engineered structures and waste acceptance requirements of radioactive waste repositories.

RepMet/05 – "RepMet Tools and Guidelines" (NEA, 2021c) supports the libraries, providing a number of tools, methods, guidelines and approaches that were either used in developing the libraries or will be useful for RWMOs when adopting and implementing the libraries.

The documents are primarily designed for use by personnel in RWMOs, regardless of whether they have a strong background or not in such areas as database management, database development, data modelling or any other area of information and/or computing systems. The documents provide high-level overviews and summaries suitable for RWMO Managers and Decision Makers, and include more detailed, implementation specific information targeted at Information Systems Developers working within a RWMO environment. See Table 1.1 for details of the intended audiences.

Table 1.1: Intended audiences for RepMet documents

Deliverable	Primary audience	Secondary audience
RepMet/01 – *Metadata for Radioactive Waste Management*	RWMO Managers and Decision Makers: • What metadata is and why it is valuable to their organisations; • Issues to consider in metadata implementation, and how RepMet proposals may be adopted; • High-level recommendations on metadata adoption and implementation at an organisational level. Information Systems Developers: • Awareness of benefits and risks in metadata implementation projects.	Local and international regulators Other concerned authorities: • Awareness of role of metadata in ensuring audit trails and long-term reliability of data, information and records. Non-specialist audiences: • Understanding of best practices in information handling in RWM, and expectations on what information should be available over the long term.

Table 1.1: Intended audiences for RepMet documents (Continued)

Deliverable	Primary audience	Secondary audience
	• Identification of possible designated communities for metadata use.	
RepMet/02 – Site Characterisation Library RepMet/03 – Waste Package Library RepMet/04 – Repository Library	Information Systems Developers: • Re-usable data models and controlled dictionaries developed and validated by RepMet. RWMO Engineers: • Awareness of attributes of interest to information systems for long-term access and use; • Agreed vocabulary for international harmonisation of terms.	Academics: • Current best practice in metadata modelling for RWMOs, as basis for further development in future.
RepMet/05 – RepMet Tools and Guidelines	Information Systems Developers: • Tools and techniques for use during the implementation process; • Recommended existing standards and how they may be applied.	RWMO managers or decision makers interested in technical aspects (eg. data modelling).

Source: NEA, 2019.

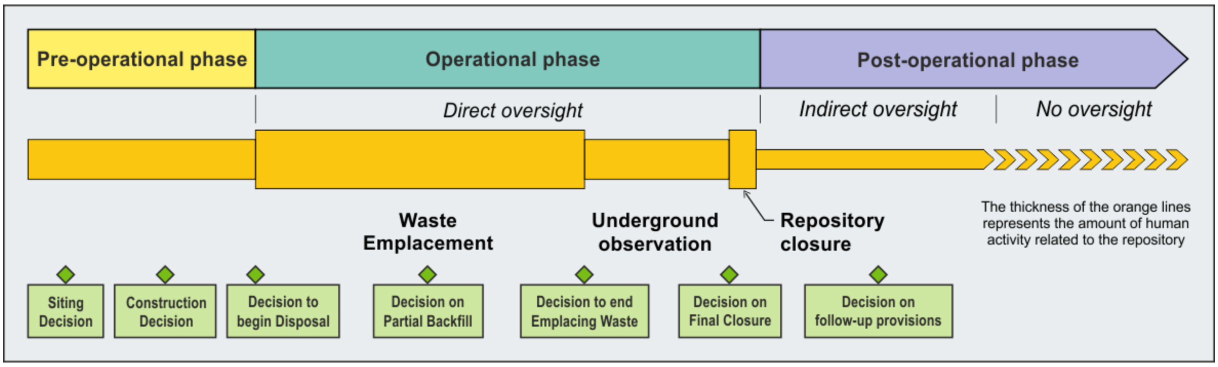
1.3. An introduction to RepMet/04 – Repository Library

The Repository Library presents a collection of data and metadata models[2] for the description of the engineered structures and waste acceptance requirements of radioactive waste repositories. The library includes examples of the application of the data models to repositories from the United States and Hungary. This document has been developed by experts from the RepMet project in discussion with external specialists.

Repositories for the storage of low-level waste (LLW), intermediate-level waste (ILW), high-level waste (HLW) and Spent Nuclear Fuel (SNF) from commercial nuclear power plants (NPPs) are all considered in the Repository Library. The phases for the development of a radioactive waste repository can be considered as pre-operational, operational and post-operational, as shown in Figure 1.2. For the Repository Library it was decided to model the repository at the time of closure, immediately following the operational phase and just prior to the post-operational phase. This decision was based on the assumption that the metadata requirements will be known in totality (maturity) at this time.

2. Please refer to the “RepMet/05 – RepMet Tools and Guidelines”, Chapter 2 – Data Modelling, for more details about data and metadata models (NEA, 2021c).

Figure 1.2: Repository life time phases



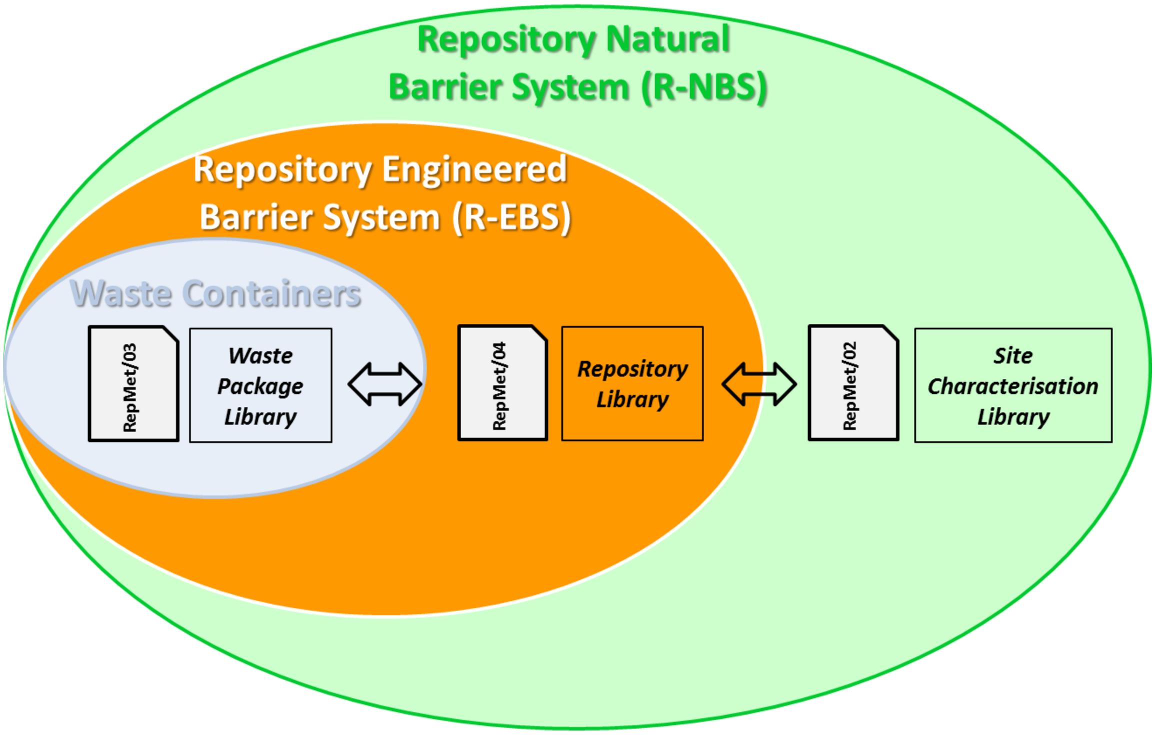
Source: NEA, 2019.

The primary objective of a radioactive waste repository is to ensure that radioactive and chemical releases to the environment are restricted to levels at or below the regulatory requirements. Disposal of radioactive waste is typically done in either geologic (deep underground) or near-surface facilities. The function of the disposal facility is to provide safe containment and isolation of the waste emplaced within for long periods of time. A repository may accomplish this through a combination of multiple barriers, both engineered and natural, that contribute to the containment, retardation and/or isolation of radioactive and chemical contaminants present in the waste. Figure 1.3 provides a graphical representation of multiple barriers in a repository contributing to the containment of radioactive and/or chemical contaminants present in the waste (see Ahn, 2010 for further information). Beginning with the waste containers, including elements such as disposal modules, overpack, wasteform 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 (R-EBS) may be added around or near the waste package emplaced in the repository to further contain radioactive and chemical contaminants in the area near the waste package. Repository Natural Barrier Systems (R-NBS) may be considered and utilise the repository host rock to ensure additional containment of radionuclide or chemical contaminates that may have breached a waste package and the R-EBS.

Figure 1.3 also illustrates where each of the RepMet Libraries fits in an overall radioactive waste management system, and each RepMet Library provides descriptions and details associated with the multiple barriers.

The RepMet group developed the Repository Library as an interconnection between the Waste Package and Site Characterisation Libraries. The Repository Library illustrates high-level conceptual data models and related controlled dictionaries to link the other two libraries as an integrated set of data and metadata necessary to assure the safe disposal of radioactive waste.

Figure 1.3: Multiple Barriers of a Repository



Source: NEA, 2019.

A common structure is used for the Repository Library, the Waste Package Library (NEA, 2021b) and the Site Characterisation Library (NEA, 2021a). For the Repository Library this is as follows:

- Chapter 2 introduces the standards that RepMet reviewed and selected for data, metadata, construction and safety requirements for a RWM repository.
- Chapter 3 presents the conceptual data models (CDMs) that RepMet created specifically for describing a RWM repository, including the entities and definitions, along with the CDMs that were obtained from the selected standards.
- Chapter 4 illustrates how the CDM introduced in Chapter 3 and developed for a RWM repository would be compatible with the selected currently operating RWM repositories.
- Chapter 5 presents the controlled dictionary including the metadata for the properties (attributes) of the entities chosen to present the RWM repository at a conceptual level.
- Chapter 6 closes the report and provides considerations for future work.

These chapters contain information about metadata-based standards and techniques at an introductory level only. For more details, see the "RepMet Tools and Guidelines" report (NEA, 2021c).

Box 1.2: Repositories for radioactive waste disposal

Research in underground disposal of radioactive waste in the United States began in earnest in the 1950s. The National Academy of Sciences released a report in 1957 concluding that disposal of radioactive wastes in salt host rocks (bedded or domal) would offer a practical, immediate solution to the problem (IAEA, 2012). This report prompted US research to focus initially on salt formations. However, over time, the United States has expanded its research to include other host rock repository concepts, and internationally, countries without salt formations focused on repository concepts in other host media such as crystalline and argillaceous host rock.

Disposal of radioactive waste is typically done in either geologic (deep underground) or near-surface facilities. The function of the disposal facility is to provide safe containment and isolation of the waste emplaced within for long periods of time. The type of disposal facility is dependent on the half-lives of disposed radionuclides. Near-surface disposal is best suited for radioactive waste comprised of short-lived radionuclides (those with half-lives less than thirty years) and long-lived radionuclides with low concentration. In a near-surface facility, radioactive waste might be emplaced in earthen trenches, above ground engineered structures, engineered structures just below the ground surface, rock caverns, silos, and tunnels excavated at shallow depths (IAEA, 2004). Due to the activity of the waste and proximity to the ground surface, near-surface disposal is not utilised for ILW or HLW.

Near-surface disposal is appropriate only for very low-level waste (VLLW) or LLW. The near-surface disposal facility may require the maintenance of active institutional controls (AICs) over the site for a period of time following closure in order to safeguard the facility and its contents from disruption due to inadvertent human intrusion. However, the long-term safe performance of the facility should not be dependent on the presence of AICs. It is usually assumed that the period of reliance on AICs is for a limited time, typically less than a few hundred years. Following the initial time period when AICs are present, effective isolation of emplaced waste is accomplished passively, and is a result of the natural containment characteristics of the site and the design of the facility.

Geological radioactive waste disposal is the emplacement of solid radioactive waste material in a facility located deep underground in a stable geologic formation. AICs may be activated at the facility for a period of time post-closure to safeguard against inadvertent human intrusion and the release of waste material into the environment. Long-term waste containment, however, is provided primarily by the characteristics of the geologic formation in which waste is emplaced as well as by engineered barriers constructed to physically and/or chemically inhibit radionuclide transport. The depth chosen for the geologic repository depends on a variety of factors, including the depth at which a stable geologic formation is located, isolation from other formations that are more transmissive, proximity to groundwater, host rock stability and composition, and the type of waste emplaced (IAEA, 2011; IAEA, 2007). Due to the limitations associated with near-surface disposal, geologic disposal is the method of choice for ILW, HLW and SNF. Due to the activity of the emplaced waste, it might be necessary that a geologic repository and engineered barriers provide containment and isolation for many thousands of years.

The location of the geologic repository must be chosen carefully. It must be at an appropriate depth, in a stable location, so that the facility is protected from disruptive processes occurring on or near the ground surface. In addition, a location removed from underground resources, such as valuable minerals and fossil fuels, reduces the likelihood of inadvertent human intrusion in the post-closure period. Ideally, the geologic repository location makes human access to the waste difficult and restricts the mobility of radionuclides emplaced inside.

2. Review of existing standards

2.1. Scope

Prior to the establishment of the Radioactive Waste Repository Metadata Management (RepMet) initiative there were a lack of national and international metadata standards that specifically supported the management of radioactive waste. This lack of domain specific standards led the Integration Group for the Safety Case (IGSC) to establish the RepMet initiative within the NEA framework with the remit to investigate the use of metadata to support and improve the management of data and information related to radioactive waste management.

The *Repository Library* is a technical report designed to show the application of metadata tools and techniques to support the engineered structures and waste acceptance requirements of radioactive waste repositories. The RepMet team reviewed a range of metadata standards, and then selected a number that, even if originally not related or designed for the management of radioactive waste repositories, are based on generic concepts and schemas that can be easily adapted and applied to this field.[3]

2.2. Selected metadata standards

RepMet selected, adapted and/or used the following standards for the implementation of the Repository Library:

- Observations and Measurements (O&M) Standard;
- Simple Knowledge Organization System (SKOS);
- Minnesota Recordkeeping Metadata Standard (MRMS).

The "RepMet Tools and Guidelines" report (NEA, 2021c) provides a detailed explanation for each of these. In addition, RepMet recognised the importance of implementing some of the metadata standards that are currently used in the field of facility construction (e.g. Building Information Modelling [BIM], UNICLASS 2015).

2.2.1. Observations and Measurements (O&M) standard

Observations and Measurements (O&M) was developed by the Open Geospatial Consortium (OGC) and is implemented as the ISO standard 19156 "Geographic information – Observations and Measurements" (Cox [ed.], Open Geospatial Consortium Inc., 2013). The O&M standard defines a conceptual data model to represent and encode observations, and, as an extension, measurements based on sampling. It structures and arranges the data and metadata in an organised and regular way that helps to maintain and

3. RepMet followed the same approach for the development of the Waste Package Library. However, a different approach was used for the Site Characterisation Library for which several well-established geoscience metadata standards are available.

preserve the information associated with an observation. Though originally developed for geographic information, this standard is generic and can be applied to many types of observational data, including those related to radioactive waste management.

The O&M standard is based on the concept of an “observation”. This is any act of observing a property of a feature of interest resulting in the estimation of a value, and involving application of specified processes such as measurement and numerical simulation. For example, in the context of the Repository Library, an observation may be the porosity (property) of the backfill in the repository tunnels (features of interest) resulting in numeric data expressed in dimensionless numbers (result), obtained through an empirical approach in a laboratory (process).

A key element of the O&M standard is that instead of using different data models for different kinds of observation, a single conceptual data model works for all. This enables improved interoperability between different information systems, and makes database development easier. The diversity of real-world observations, including those from the management of radioactive waste, is implemented through the adoption of appropriate and specific controlled dictionaries for the elements of the O&M conceptual model. The addition of new fields or new types of observation is undertaken by updating these controlled dictionaries. RepMet has created specific controlled dictionaries to support the observable properties related to repository requirements and structures at the time of closure. These original controlled dictionaries have been developed using SKOS and are described in Chapter 5.

2.2.2. Simple Knowledge Organization System (SKOS)

Simple Knowledge Organization System (SKOS) is a World Wide Web Consortium (W3C) standard to represent “knowledge organisation systems” - taxonomies, thesauri and other types of structured controlled dictionaries.

SKOS is built on Resource Description Framework (RDF), a W3C standard for the conceptual description or modelling of information about web resources – that is, anything that can be identified through a location on the Web. SKOS is a RDF vocabulary to create RDF databases about structured controlled dictionaries with their hierarchical and semantic relations.

The Repository Library includes a web-based controlled dictionary developed according to the SKOS standard, which details the observable properties related to repository requirements and structures at the time of closure. The use of the SKOS vocabulary allowed the development of a RDF database containing detailed information as to why a Radioactive Waste Management Organisation (RWMO) should collect data about specific observable properties or related general comments. This helps to identify and maintain the core information about requirements and structures of a radioactive waste repository at the time of closure.

2.2.3. Minnesota Recordkeeping Metadata Standard

Minnesota Recordkeeping Metadata Standard (MRMS) is a standard that the Recordkeeping Metadata Development Committee of the US State of Minnesota developed to facilitate record management at the governmental level, releasing version 1.3 of MRMS in 2015. It shares many of its elements with other metadata standards, such as the Dublin

Core[4] and ISO 19115[5]. Apart from information on format, location and access, MRMS provides elements to describe responsible parties, management, preservation history, and all administrative details that are relevant for the life cycle of material in hardcopy, analogue or digital form. See reference (RMDC, 2015) for more details.

RepMet considered that the use of MRMS for record-keeping at the government level provides a good basis for record-keeping within RWMOs. It has also been tested and used by PURAM (Hungary). RepMet therefore adopted and adapted the MRMS to provide the framework for record-keeping integrated into the metadata models that the initiative developed. The integration of the MRMS and the O&M metadata models provides a global schema to encode observations and their records.

2.2.4. Standards for facility construction

When constructing a facility for a RWM repository, it will be necessary to follow the building standards and codes in force in the locality where the facility is being developed. There may also be benefit in following a structured project management approach to the construction and operation of a RWM facility.

One such approach is Building Information Modelling (BIM) (Ruffle, 1986). BIM describes the process of designing a building collaboratively using one coherent set of computer-based models rather than as separate sets of drawings. BIM solutions and approaches are available commercially through many software suppliers. UNICLASS 2015 is standard unified classification system for all sectors of the UK construction industry. It is used to classify items of all scales – from the very small to the large – allowing for project information to be structured to a recognised standard. UNICLASS 2015 is compatible with BIM and is compliant with ISO 12006 (ISO, 2015).

4. Dublin Core: The Dublin Core Metadata Initiative provides a simple model for general-purpose metadata. There is significant overlap with ISO19115. (See DCMI Usage Board, http://dublincore.org.)

5. ISO 19115 (Geographic information – Metadata) is a generic spatial-metadata standard (Open Geospatial Consortium [n.d.], retrieved from www.iso.org/obp/ui/#iso:std:iso:19115:ed-1:v1:en).

3. Conceptual data models

3.1. Scope

A “data model” is an abstract representation of the structure and logical organisation of a database. A database is an organised collection of data about a specific business area of interest, such as the requirements and structures for a radioactive waste repository at the time of closure in the case of the Repository Library.

A “conceptual data model” (CDM) is a high-level data model intended to represent the semantics of an entire domain of interest. It describes the organisation and the structure of a database in terms of objects of interest (i.e. *entities*) together with their descriptive characteristics (i.e. *attributes*) and logical associations among them (i.e. *relationships*). A CDM is not related to the software and hardware used to create a database, so allowing database designers to represent data independently from information systems. For more details, the “RepMet Tools and Guidelines” report (NEA, 2021c) contains a specific section dedicated to data modelling.

For the development of the Repository Library, RepMet created an original CDM to structure and organise the data about the repository requirements and structures at the time of closure. This CDM is an original product of the RepMet initiative and is not part of any of the selected standards reported in Chapter 2. However, the Repository Library also relies on CDMs from the MRMS and O&M Standard. Items of data related to the attributes of the Repository Library CDM are supported by items of metadata coming from these standards and arranged in analogous CDMs. The CDM is the backbone of the Repository Library. Within the CDM:

- Entities are “*real-world*” objects related to the repository requirements and structures at the time of closure. Each entity is associated to a list of attributes that constitute the basic elements of the identified core information about repository requirements and structures.
- Metadata are connected to data and vice-versa. RepMet recognised the importance of effectively structuring the collection of data about a library topic into a data model, before using the metadata sets from the selected standards.

The design of the CDM ensures that the Repository Library is well defined and is suitable for customisation and implementation by RWMOs within a data storage system; though the specification of an IT system for a specific database implementation is outside the remit of RepMet.

Box 3.1: RepMet Terminology - Attribute vs Data

In the terminology adopted by RepMet, “attribute” and “data” are two sides of the same coin. Attribute is a property or a characteristic of interest in a database, Data is the value (for example, a number, a function, a string or some text) that an attribute can assume. For example, if “total beta/gamma activity” is the attribute about a radioactive waste, then “150 kBq” may be the numeric data value.

3.2. Repository Library CDM

The Repository Library CDM is represented using entity relationship diagrams (ERDs). An ERD is a formal technique for visualising a data model using specific notations to depict data in terms of entities, the attributes of those entities, and the relationships between entities. This is explained in more detail in Chapter 2 of the “RepMet Tools and Guidelines” report (NEA, 2021c).

3.2.1. Entities and relationships

The Repository Library CDM is composed of six entities – see Figure 3.1. The entities represent typically “real-world” objects in a radioactive waste repository, such as an engineered barrier, and also guidance or requirements for a specific facility, such as the waste acceptance criteria (WAC). The choice of entities was based on the advice of subject matter experts as well as from a review of selected reports on the development of radioactive waste repositories (see Mariner, 2011; SKB, 2016; Sevougian, 2016).

Figure 3.2 shows both the Repository Library CDM, and the relationship between this and the other two RepMet Libraries – the Site Characterisation Library (NEA, 2019a) and the Waste Package Library (NEA, 2021a).

The entities and their definitions are reported in Table 3.1. IAEA definitions (IAEA, 2007) have been used as a starting point for each of the definitions in the table. However, a number have been modified in order to:

- Ensure self-consistency within the CDM;
- Add flexibility to the CDM to ensure that it can meet the needs of the diverse range of radioactive waste repositories used by RWMOs worldwide.

3.2.2. Attributes

Each entity has an associated set of attributes that describe the entity and that were assembled from a number of sources. For example, the hydraulic conductivity is a property of an engineered barrier, because it is related to a barrier’s ability to halt or retard the migration of radionuclides in the event of a breach of a waste container. The lower the hydraulic conductivity, the more the advective transport through the media (i.e. the buffer) is limited (safety function). See Chapter 5. for more information on the RepMet work in developing the attributes of the Repository Library CDM.

Box 3.2: What are cardinalities?

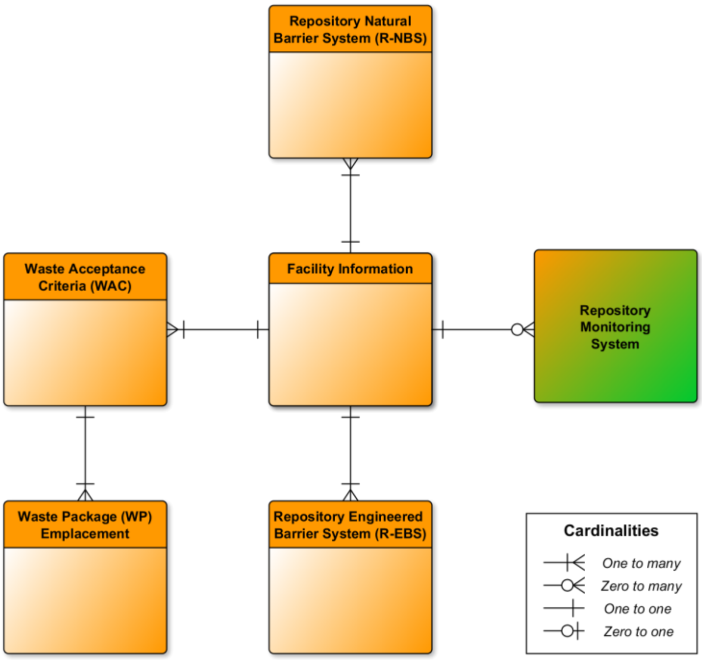
Each relationship in an ERD has an associated cardinality. This describes the minimum and the maximum number of occurrences of one entity that may be related to a single occurrence of the other entity. Because all relationships are bidirectional, cardinality must be defined in both directions for every relationship. The cardinality is represented on the ERD through the use of a graphical marker on each end of the relationship as is shown in the legend in Figure 3.1. Cardinalities are explained in more detail in Chapter 2 of the RepMet Tools and Guidelines report (NEA, 2021c).

Table 3.1: Repository Library CDM – Entity Definitions

Entity	Definition
facility information	- repository: a nuclear facility where waste is emplaced 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.
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.
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. Properties for this entity come from the RepMet Site Characterisation Library (NEA, 2021a).
repository monitoring systems	- 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. Specific properties for this entity come from the RepMet Site Characterisation Library (NEA, 2021b).
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.
waste package emplacement, WP emplacement	- describes the way waste packages are placed in the repository for final disposal. Such placement may include, for example, vertical or horizontal placement in drifts, or placement in boreholes. Much of the data for this entity is derived from the RepMet Waste Package Library (NEA, 2021a).

Source: NEA, 2019.

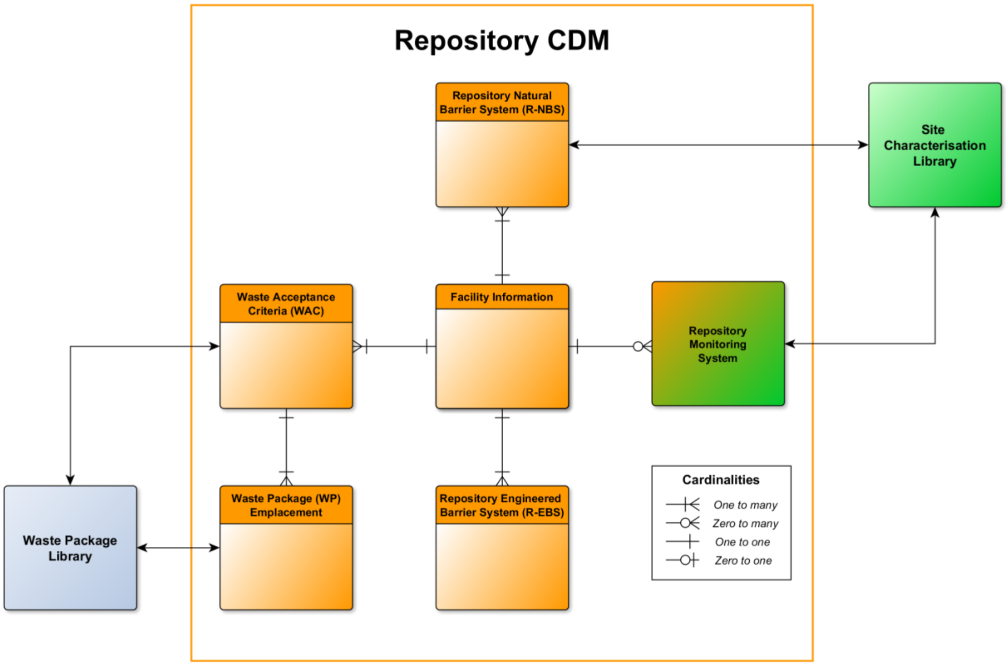
Figure 3.1: Repository Library CDM – Entity Relationship Diagram



Source: NEA, 2019.

The Repository Monitoring System entity differs from the others in that it is a “macro-entity” to be detailed in the “Environmental Monitoring CDM” of the Site Characterisation Library (Open Geospatial Consortium, 2007). The Environmental Monitoring CDM can be applied to a range of generic monitoring systems, not just in the geoscience field. Its application to monitoring systems for radioactive waste repositories can be carried out by using controlled dictionaries to be developed specifically for radioactive waste repositories.

Figure 3.2: Interconnection between the CDMS of the RepMet Libraries



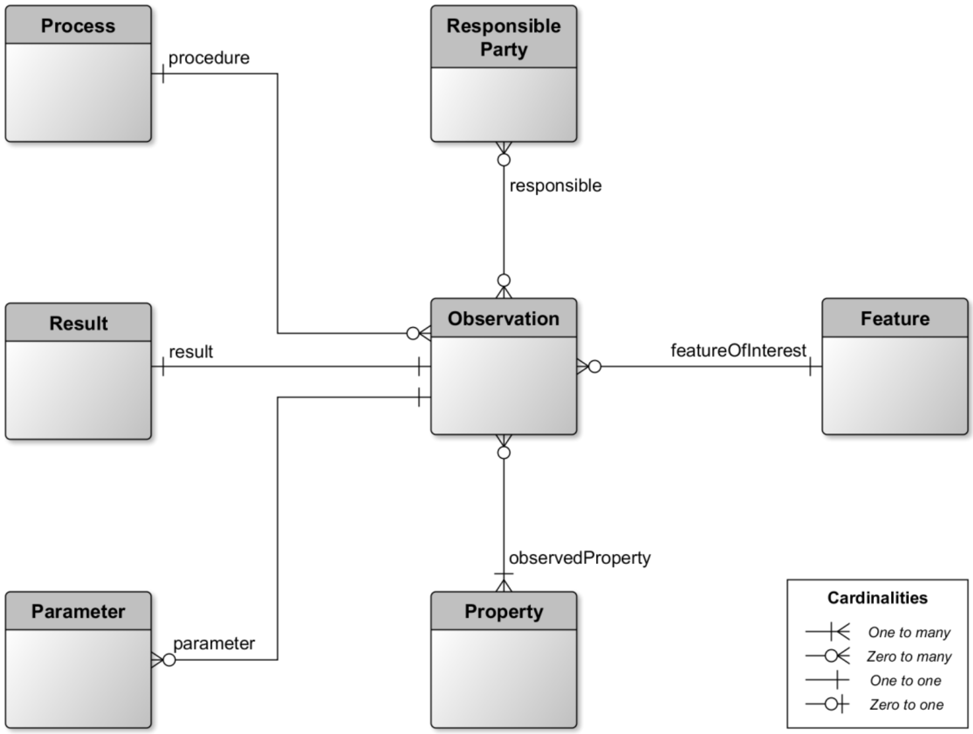
Source: NEA, 2019.

3.3. CDMs from the O&M standard and MRMS

O&M and MRMS are metadata standards that RepMet included in the design of the CDM for the Repository Library. These standards are based on their own data models which have been interpreted at a conceptual level and converted to the ERD notation for consistency with the Repository Library CDM (Figure 3.1). Figure 3.3 illustrates the CDM of the O&M Standard.

These standards and the CDMs that RepMet developed are introduced and explained in the Tools and Guidelines report (NEA, 2021c).

Figure 3.3: Observations and Measurements CDM – Entity Relationship Diagram

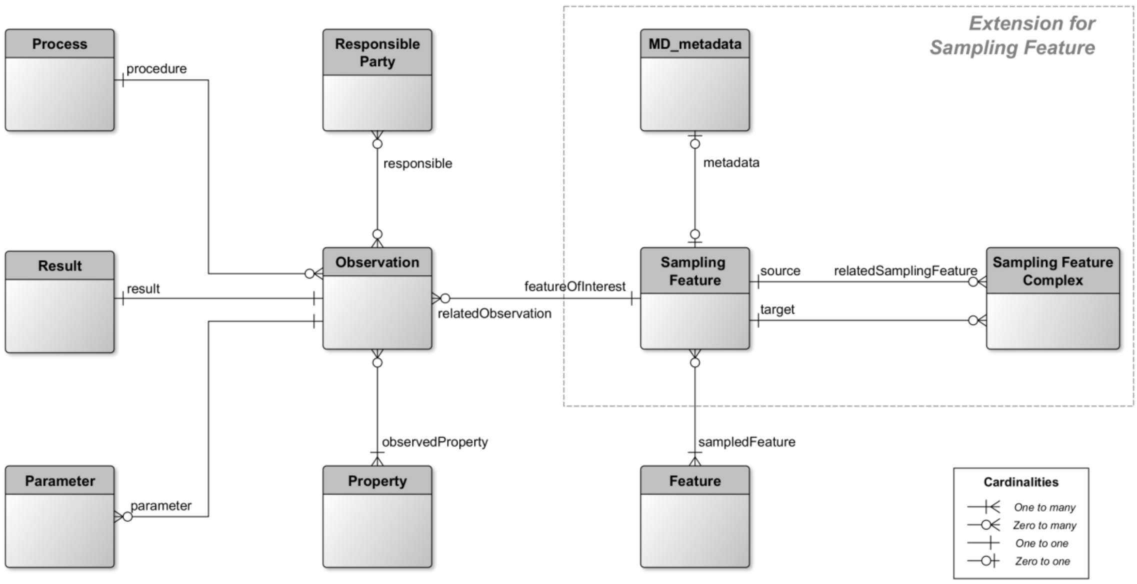


Source: NEA, 2019.

The basic O&M standard can be used to model any kind of *direct* observations. In order to use the O&M standard to model *indirect* observations, it is necessary to adopt the "Sampling Feature" extension (Open Geospatial Consortium, 2007).

Indirect observations include, for example, observations involving sampling techniques where a measurement can be used to infer the value of a property of a feature of interest. These sampling features provide a link between features of technical interest and the observation metadata. Sampling features are often related to each other, as parts of associated sets or *complexes*, through sub-sampling, etc. Figure 3.4 illustrates the CDM of the O&M standard including the extension for the sampling features.

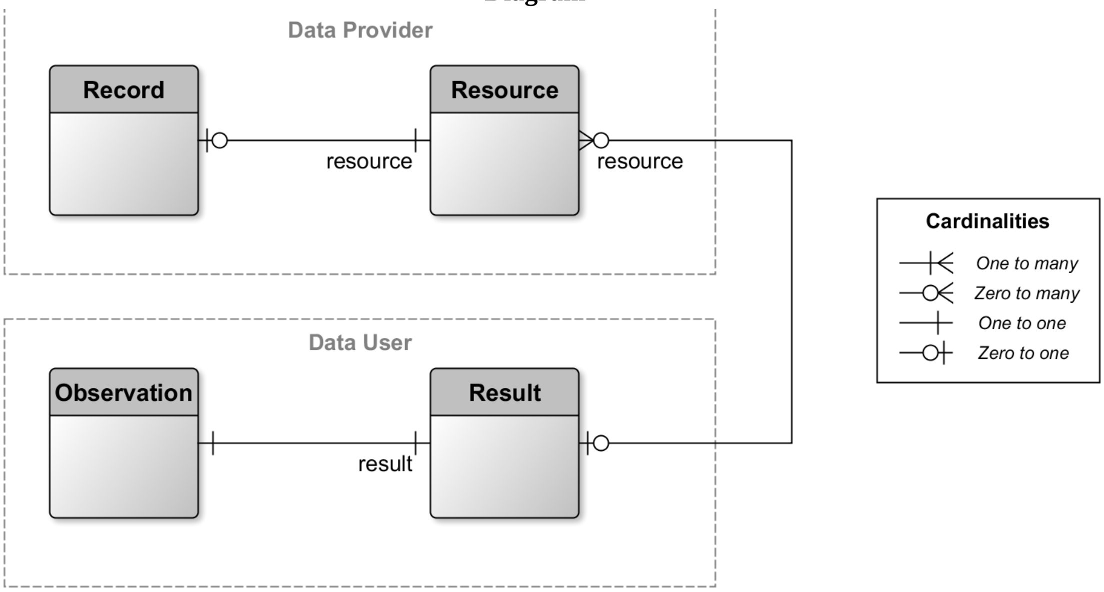
Figure 3.4: Observations and Measurements CDM with Sampling Feature extension



Source: NEA, 2019.

Figure 3.5 illustrates how the MRMS can be interpreted in a CDM and integrated with the O&M CDM.

Figure 3.5: Minnesota Recordkeeping Metadata Standard CDM - Entity Relationship Diagram

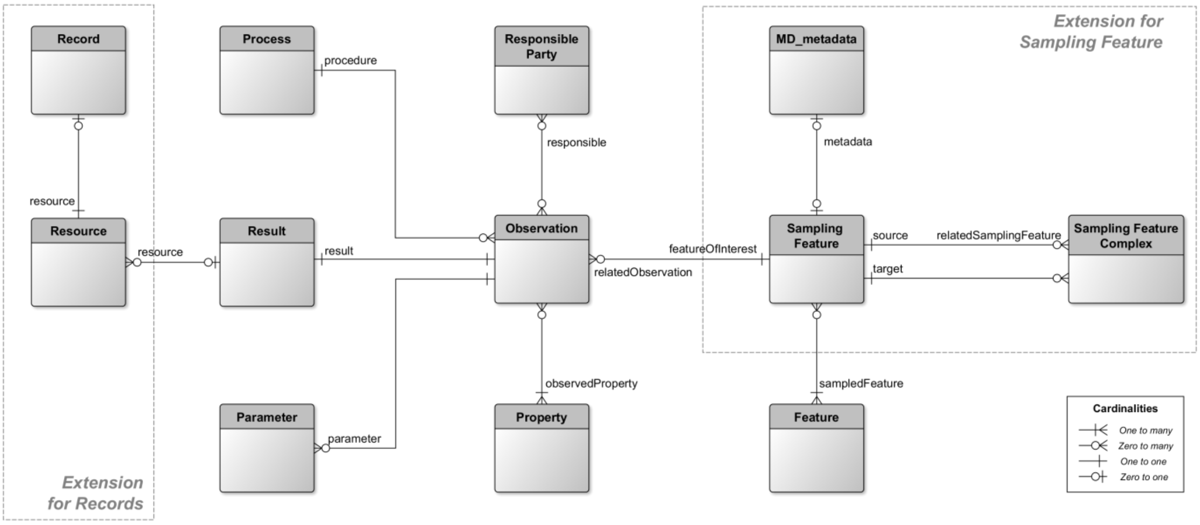


Source: NEA, 2019.

Within the MRMS CDM the *Resource* is the set of metadata elements needed to find and access information stored on a tangible, electronic or other medium that is retrievable in a usable form, while the *Record* is the set of administrative metadata elements and the reference to the Resource that is the subject of record-keeping.

Figure 3.6 illustrates the O&M CDM including the sampling feature extension and the integration with the MRMS CDM.

Figure 3.6: O&M Standard with Sampling Feature extension and MRMS in integrated CDM form



Source: NEA, 2019.

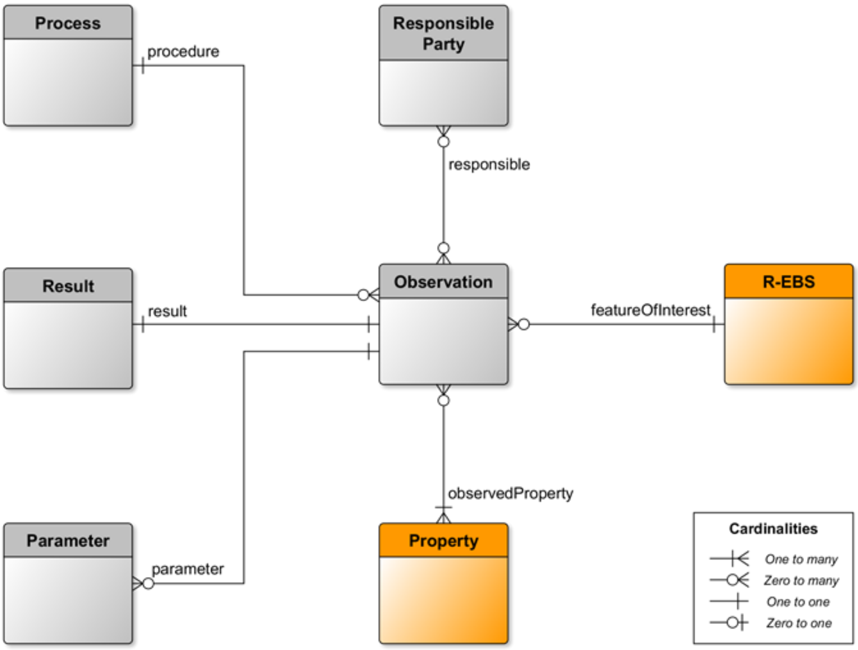
The attributes for the entities in Figures 3.3 to 3.5 are described in the RepMet Tools and Guidelines report (NEA, 2021c).

3.4. Connection between Repository Library and O&M CDMs

The implementation of the O&M standard and the MRMS in the conceptual design for the database to support repository requirements and structures at the closure, and is intended to demonstrate how metadata can support the long-term management of the data and information within the database. It shows how the CDMs created to support repository requirements and structures at the closure can be supported and integrated with the CDMs of the selected metadata standards.

- The entities of the Repository Library CDM (Figure 3.1) that represent the real-world objects from the field of radioactive waste management, can be represented as “*features of interest*” according to the O&M standard.
- The attributes of the entities may be the properties of a *feature of interest*, such as a waste package emplacement or a repository engineered barrier, that are estimated during an observation process, where the type of observation depends on the type of attribute.

Figure 3.7: Integration of Repository Library CDM with the O&M CDM



Source: NEA, 2019.

Figure 3.7 illustrates the linkage between the Repository Engineered Barrier System (R-EBS) entity and an associated Observation. Other entities within the Repository Library, such as the Repository Natural Barrier System (R-NBS) can also be linked to an associated Observation.

4. Example applications of the CDMs

From a general point of view, a CDM provides a schema describing the structure of a database, with a CDM instance being the application of that schema for a real-world object such as an existing planned facility for radioactive waste disposal, or an abstract object, such as an observation.

To illustrate how the Repository CDM presented in Chapter 3 can be applied in practice, this chapter illustrates how several real-world, existing or planned facilities for radioactive waste disposal can be mapped to the entities of the Repository CDM.

4.1. Example applications of the Repository Library

This chapter illustrates how radioactive waste repositories can be mapped to the entities of the Repository CDM. It uses examples from:

- United States, with courtesy of the US Department of Energy (DOE) Sandia National Laboratories;
- Hungary, with courtesy of the Public Limited Company for Radioactive Waste Management.

The examples help to show how to apply the Repository CDM, in order to capture technical and other related details about the repository requirements and structures.

4.1.1. US repository example - Waste Isolation Pilot Plant (WIPP)

The Waste Isolation Pilot Plant (WIPP) consists of a deep underground mined facility located in a bedded salt formation in south-eastern New Mexico, United States. The WIPP has been developed by the DOE for the geologic disposal of transuranic (TRU) waste[6]. At WIPP, the TRU waste is classified as either contact handled (CH) or remote handled (RH) based on the contact dose rate at the surface of the waste container[7].

The waste disposal area of the WIPP is located 655 metres below the ground surface. The facility consists of ten waste disposal panels. In the disposal area (the right-hand regions in Figure 4.1), there are four eastern waste panels, four western waste panels and two panels comprised of the drifts between western and eastern panels. WIPP is currently licensed to dispose of 176 564 m^3 of TRU waste: 7 079 m^3 of RH-TRU and 168 485 m^3 of CH-TRU waste. CH-TRU waste is placed on the floor of disposal rooms. RH-TRU waste is placed in boreholes located in salt ribs between disposal rooms. Containment of TRU waste at the

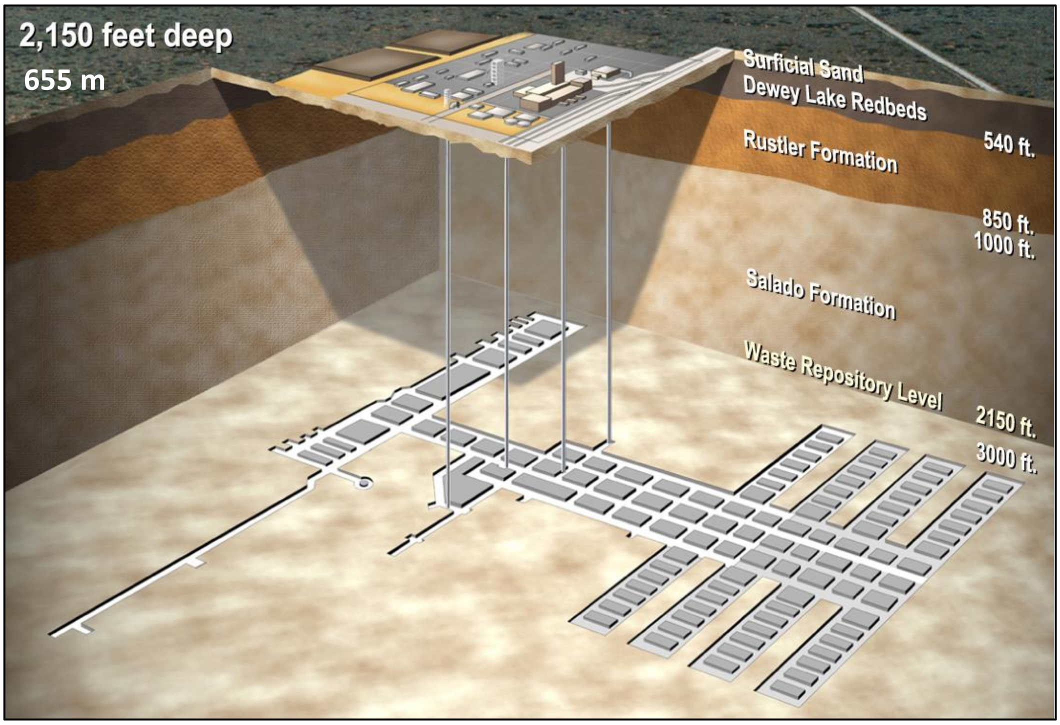
6. According the US legislation, TRU waste is waste containing alpha particle emitting radionuclides with a half-life greater than 20 years in concentrations greater than 3.7 kBq/g.

7. If the contact dose rate is less than 2 mSv/h, the waste is defined as CH-TRU. If it is greater than or equal to 2 mSv/h, the waste is defined as RH-TRU.

WIPP is regulated by the US Environmental Protection Agency (EPA). TRU waste acceptance criteria for the WIPP are delineated in the *Transuranic Waste Acceptance Criteria for the Waste Isolation Pilot Plant* (US DOE, 2016a).

Access mains are located north of the waste disposal region, and connect to four shafts that allow for mined salt removal, waste transport from the surface to the disposal panels, and inflow to and exhaust of air from the repository. North of the four panels are excavated regions used for experimental activities during the developmental phase of the WIPP.

Figure 4.1: The Waste Isolation Pilot Plant (WIPP)



Source: Sandia National Laboratories, 2019.

Figure 4.2: Supersacks of MgO emplaced on top of WIPP waste

Source: Sandia National Laboratories, 2019.

Magnesium oxide (MgO) is placed in the WIPP to meet the requirements for multiple natural and engineered barriers (US DOE, 2014a). The EPA specified MgO as the only engineered barrier in the WIPP disposal system because the Agency considered panel closures, shaft seals and borehole plugs to be part of the disposal system design. MgO acts as a barrier by decreasing actinide solubilities through the consumption of essentially all the carbon dioxide produced should microbial activity consume all of the cellulosic, plastic, and rubber materials in the TRU waste, waste containers and waste-emplacement materials in the repository. As microbial activity is an uncertain process, the MgO engineered barrier reduces uncertainty in the repository chemical conditions by ensuring low carbon dioxide fugacity and by controlling pH. MgO contained in polypropylene supersacks is placed on top of waste stacks using a forklift. Figure 4.2 shows supersacks of MgO emplaced on top of WIPP waste stacks.

WIPP monitoring activities are performed as an assurance measure to detect substantial and detrimental deviations from expected disposal system performance (US DOE, 2014b). This monitoring programme consists of pre-closure and post-closure activities that do not jeopardise the isolation of the waste. The monitoring programme must be conducted until the DOE and the EPA agree that there are no significant concerns to be addressed by further monitoring. The long-term performance expectations for the disposal system are derived from conceptual models, scenarios, and assumptions developed for the WIPP Total System Performance Assessment (TSPA) (See Box 4.1 for more details on the TSPA). Ten parameters are monitored during the pre-closure period, namely creep closure and stresses, the extent of brittle deformation, the initiation of brittle deformation, the displacement of deformation features, changes in groundwater composition in the Culebra Dolomite Member of the Rustler Formation, changes in Culebra groundwater flow, the drilling rate, the probability of encountering a brine reservoir in the Castile formation, subsidence and waste activity. The data used to determine the ten monitoring parameters are generated by five separate monitoring programmes. Each monitoring programme focuses on the collection of field data. Results from monitoring programmes are generated on an ongoing basis throughout the operational phase of the repository. The plan for post-closure monitoring will be revisited by the DOE before the end of WIPP facility operations.

All these concepts about the WIPP repository can be described using the data model for the Repository CDM (see Figure 3.1) and are shown in Table 4.1. It should be noted that while all entities of the Repository CDM are considered, only a representative subset of the attributes are used to illustrate the ability to describe the WIPP metadata with the Repository CDM.

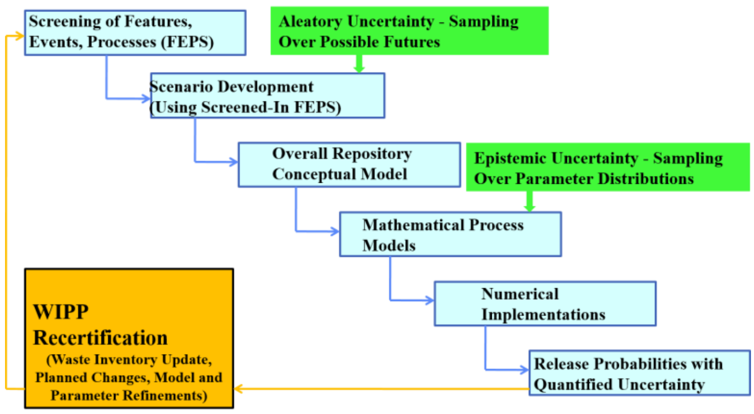
Table 4.1: Repository CDM (including example attributes) applied to the WIPP repository for TRU waste

Entity	Example of attributes		Attribute values
Facility Information	Facility identification		Waste Isolation Pilot Plant (WIPP)
	Building identification		NM 4890139088
	Site identification		32°22′11′′N 103°47′30′′W
	Waste type description		Transuranic (US Defence related)
	Capacities\Volume		7 079 m^3 RH-TRU
			168 485 m^3 CH-TRU
R-EBS	R-EBS Component	Type	Buffer
		Description	MgO Barrier
		Safety function	Decrease actinide solubility
		Other Waste	220l standard or 400l standard drum
Repository Monitoring System	Seismologic Monitoring		Data coming from monitoring system at WIPP to be structured according to the data models of the O&M standard.
	Fluid Monitoring		
	Drilling Monitoring		
	Waste inventory Monitoring		
R-NBS	General properties	Gas permeability	Data coming from characterisation of the WIPP site to be structured according to the data models of the O&M standard.
		Liquid permeability	
		Effective porosity	
		Fracture characteristics	
		In-situ chemistry	
		Matrix partition coefficients	
		Prohibited physical properties	Liquid waste
		Prohibited hazard properties	Explosive, corrosive materials and compressed gases.
WP Emplacement	Disposal vault [1]	ID	Panel 1/10 – Room 1/8
		WP or disposal module capacity	2 250 m^3 CH-TRU
		Dimensions/Vault seal length	91.44 m (300 ft)
		Dimensions/Vault seal width	10.05 m (33 ft)
		Dimensions/Vault seal height	3.96 m (13 ft)

Box 4.1: WIPP Total System Performance Assessment (TSPA)

The DOE demonstrates compliance with regulatory containment requirements TSPA calculations (IAEA, 2004). In the WIPP context, TSPA is designed to address three primary questions about the WIPP: 1) what processes and events that might affect the disposal system could take place at the WIPP site over the next 10 000 years? 2) how likely are the various processes and events that might affect the disposal system to take place at the WIPP site over the next 10 000 years? 3) what are the consequences of the various processes and events that might affect the disposal system that could take place at the WIPP site over the next 10 000 years? In addition, accounting for uncertainty in the parameters of the TSPA models leads to a further question: 4) how much confidence should be placed in answers to the first three questions? These questions give rise to a TSPA methodology for quantifying the probability distribution of possible radionuclide releases from the WIPP repository over the next 10 000 years and characterising the uncertainty in that distribution due to imperfect knowledge about the parameters contained in the models used to predict releases. This methodology is illustrated in Figure 4.3.

Figure 4.3: The WIPP TSPA Methodology



Source: Sandia National Laboratories, 2019.

The WIPP TSPA methodology begins with a FEPS screening analysis that determines what is to be considered in the analysis. FEPs are screened according to probability, consequence and regulation. From the set of retained FEPs, the scenarios to be implemented in the TSPA are constructed. The necessary scenarios inform the overall repository conceptual model, which is comprised of numerous sub-models. There are currently twenty-four conceptual models that comprise the overall WIPP conceptual model, and they are shown in Figure 4.4.

Underlying processes that comprise the conceptual models are described mathematically, and implemented numerically. Numerical simulations are performed to quantify release probabilities for the WIPP with uncertainty also quantified.

Quantified release probabilities and their associated uncertainties are then compared to regulatory containment requirements to demonstrate regulatory compliance of the facility.

Figure 4.4: WIPP TSPA Conceptual Models

- Disposal system geometry
- Culebra hydrogeology
- Repository fluid flow
- Salado
- Impure halite
- Salado interbeds
- Disturbed rock zone
- Actinide transport in Salado
- Units above the Salado
- Dissolved transport in Culebra
- Colloidal transport in Culebra
- Exploration boreholes
- Cuttings/Cavings
- Spallings
- Direct brine release
- Castile and brine reservoir
- Multiple intrusions
- Climate change
- Creep closure
- Shafts and shaft seals
- Gas generation
- Chemical conditions
- Dissolved actinide source term
- Colloidal actinide source term

Source: Sandia National Laboratories, 2019.

4.1.2. Hungarian repository example - National Radioactive Waste Repository (NRWR)

The National Radioactive Waste Repository (NRWR), which is near the village of Bátaapáti, is designed to accommodate all operational and decommissioning LILW radioactive wastes arising from the Paks NPP.

The NRWR facility consists of two parts: the surface and the underground facilities, located approximately 250 metres below the surface (see Figures 4.5 and 4.6). Both parts of the site are divided into two segments: the radiological protection controlled zone and the supervised zone. As construction is taking place in parallel with the disposal of radioactive waste, both surface and underground areas have two parts: one where radioactive waste management operations take place and the other supports the construction requirements of the underground facility. Two access tunnels connect the surface and the underground parts of the facility. One tunnel serves as access to the disposal chambers that are part of the radiological protection controlled zone, and the other serves as access to the construction area, situated in the supervised zone. Construction of the NRWR is being implemented in several phases, and the licensing of commissioning of facility elements is aligned to the phases of the implementation.

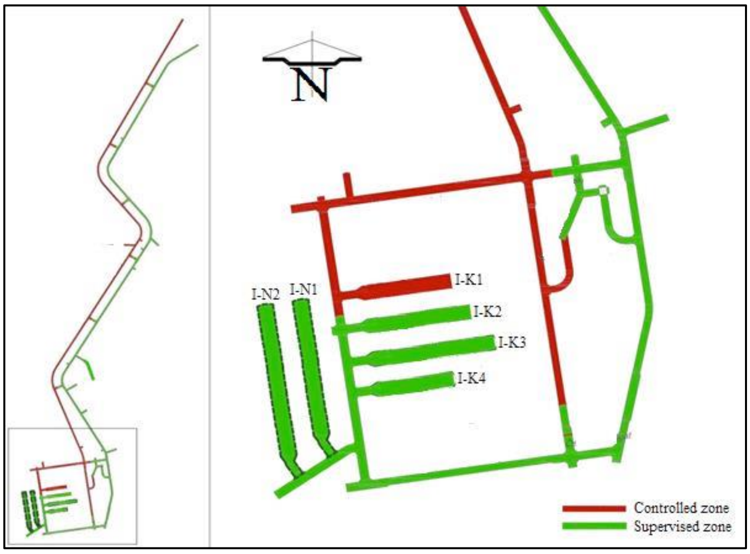
The surface facilities were constructed in 2008, and since then have been in normal operation. So far (as of September 2017) 6 536 drums filled with LILW have been transported to the site from the Paks NPP. All essential information generated in connection with the individual waste packages are electronically recorded in the waste registry system with all packages being labelled with an ID. During the acceptance of the radioactive wastes, the operator of the disposal facility confirms compliance with the waste acceptance requirements with the necessary controls.

The maximum number of 200 litre drums that can be stored in the technological building is 3 000. Radioactive waste in 200 litre drums is stored in the technological building until the drums are cemented into reinforced concrete disposal containers, nine drums in each container. The gaps between the drums are filled with inactive mortar, and, after seven days of hardening, containers are transported into the underground disposal chamber I-K1 (see Figure 4.7). This disposal concept is mapped according to the CDMs of the Waste Package Library (NEA, 2021a) in section 4.1.2.1 (*Reinforced Container Disposal Unit*).

In 2012, the underground section of the repository system was commissioned, and the facility started to accept wastes in the first chamber. The first disposal chamber was completely filled up with concrete containers in May 2017.

Figure 4.5: Aerial photograph of the surface site of the NRWR

Figure 4.6: Underground facilities of the NRWR



Source Figures 4.5 and 4.6: PURAM, 2019.

Figure 4.7: Steps towards the final disposal of waste in the NRWR (emplacement of drums in concrete containers, transportation and final disposal)

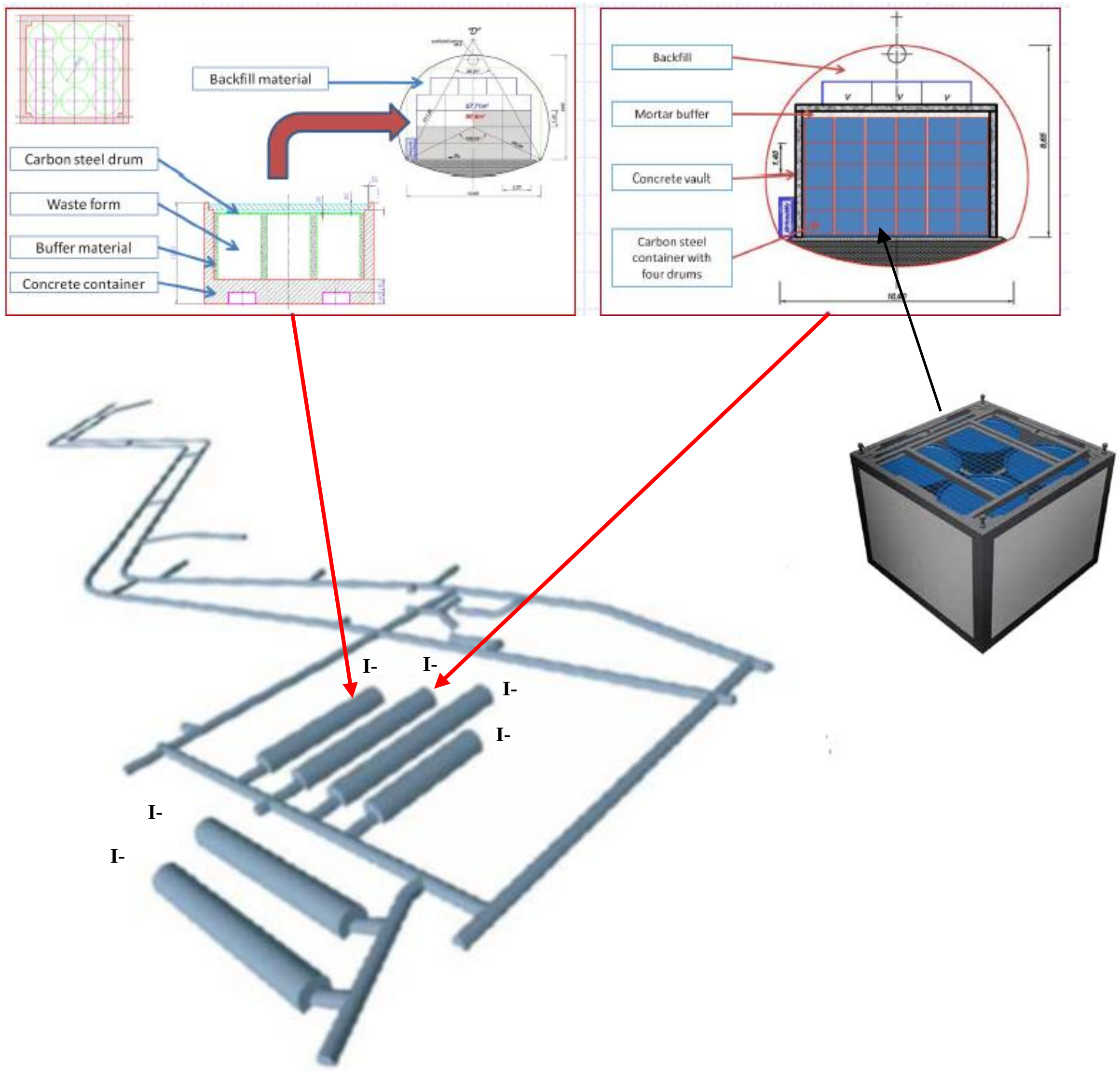
Source: PURAM, 2019.

The ongoing activities at the site and in the repository system follow the principle of "design as you go," meaning that many aspects of the project (wasteforms, chamber geometry, orientation, etc.) may change in the future to maximise the safety and efficiency of the entire facility. In parallel with commissioning the first disposal chamber, the design of new chambers of the NRWR has started based on a new arrangement concept. The basis of the new concept is that instead of the currently used reinforced containers a new waste package will be introduced. This is a metal container that is able to accommodate four drums, in which the empty space is filled with active cement pulp produced from the liquid waste on the site of the NPP. The emplacement of the so called compact waste package is planned in the reinforced concrete vault constructed within the underground disposal chamber. In the previous arrangement, the reinforced concrete container was a part of the engineered barrier system, and its functions are now taken over by the reinforced concrete vault built into the chamber. Also this disposal concept is investigated and mapped according to the data models of the Waste Package Library in the section 4.1.2.2 of the Waste Package Library (NEA, 2021a).(*Compact Waste Package*). Disposal chamber I-K2 was constructed in compliance with these plans (Figure 4.8). A safety assessment was prepared to support the new arrangement concept, which demonstrated its feasibility (see Box 4.2 for more details).

Measurement programmes have been established by the Public Limited Company for Radioactive Waste Management (PURAM) and approved by the regulatory body, for monitoring the environment and the radiation conditions of the NRWR. The purpose of this long-term environmental monitoring is to provide continuous information on the extent, regularity and trend of the impacts of natural and artificial processes. It is composed of three main parts: the geological-hydrogeological, radiological and the conventional environmental monitoring. The geotechnical (geological) monitoring system (seismo-acoustic measuring systems and deformation measuring devices) provides for the continuous monitoring of the conditions in the subsurface area, while the monitoring of the condition of the geological barrier around the repository is solved by the hydrogeological monitoring system (measurement of the changes in the water pressure and examination of the hydro-chemical parameters). The conventional environmental monitoring includes the measurement of the meteorological parameters, the survey of pollutants (dust, nitrogen dioxide) in the air, the observation of toxic trace elements in watercourse sediments (from the wider environment) and those originating from the traffic along the road to the repository, as well as the measurement of the noise level.

All these concepts about the NRWR repository can be described using the data model for the Repository CDM (see Figure 3.1) and are shown in Tables 4.2 and 4.3. It should be noted that while all entities of the Repository CDM are considered, only a representative subset of the attributes are used to illustrate the ability to describe the NRWR metadata with the Repository CDM.

Figure 4.8: Change of the disposal concept of the NRWR: Placing several containers into a reinforced concrete vault, rather than using reinforced concrete for each container, maximises efficiency of disposal



Source: PURAM, 2019.

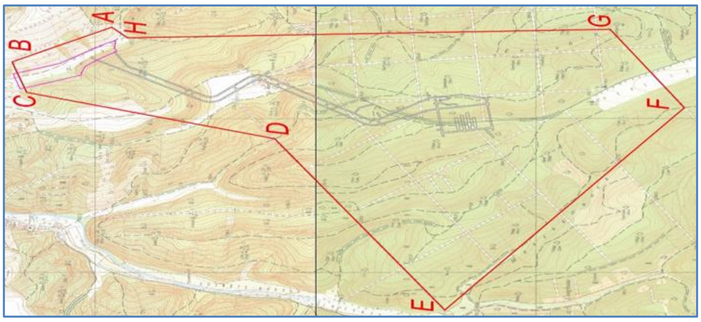
Table 4.2: Repository CDM applied to NRWR repository for LILW (1)

Entity	Example of attributes		Attribute values
Facility Information	Facility identification		NRWR
	Site identification		EOV[8] co-ordinates of the protection zone of NRWR
	Waste type description		Solid or solidified LILW from the operation and decommissioning of Paks NPP.
R-EBS	R-EBS Component [1]	Type	Backfill
		Description	Cement
		Safety function	Containment, isolation, limitation and retardation for releases of radionuclides.
	R-EBS Component [2]	Type	Seal plug
		Description	Concrete
		Safety function	Restoring the isolation of hydraulic compartments in the geosphere originally separated by a sealing fault zone that had been penetrated by access tunnels
Repository Monitoring System	Seismologic Monitoring		Data coming from monitoring system at NRWR to be structured according to the data models of the O&M standard. Among the monitored phenomena: air pollutants (dust, nitrogen dioxide), Continuous γ-dose rate measurements, sediment sampling from the creek beds for 90Sr and γ measurements, deformation controlling the impact caused by the excavation of repository chambers.
	Fluid Monitoring		
	Drilling Monitoring		
	Conventional environmental monitoring		
	Radiological Monitoring		
R-NBS	General properties	Gas permeability	Data coming from characterisation of the NRWR site to be structured according to the data models of the O&M standard.
		Liquid permeability	
		Effective porosity	
		Fracture characteristics	
		In-situ chemistry	
		Matrix partition coefficients	

Source: NEA, 2019.

8. EOV is a plane projection system used uniformly for the Hungarian civilian base maps and, in general, for spatial informatics. Below the EOV coordinates for the NRWR repository.

	EOV Y	*EOV X*	*Z [m Bf]*
A	616 593	96 926	160
B	616 368	97 378	173
C	616 170	97 312	165
D	615 869	96 187	199
E	614 756	95 415	171
F	616 070	94 328	258
G	616 580	94 665	237
H	616 524	96 853	162



Source: PURAM, 2019.

Table 4.3: Repository CDM applied to NRWR repository for LILW (2)

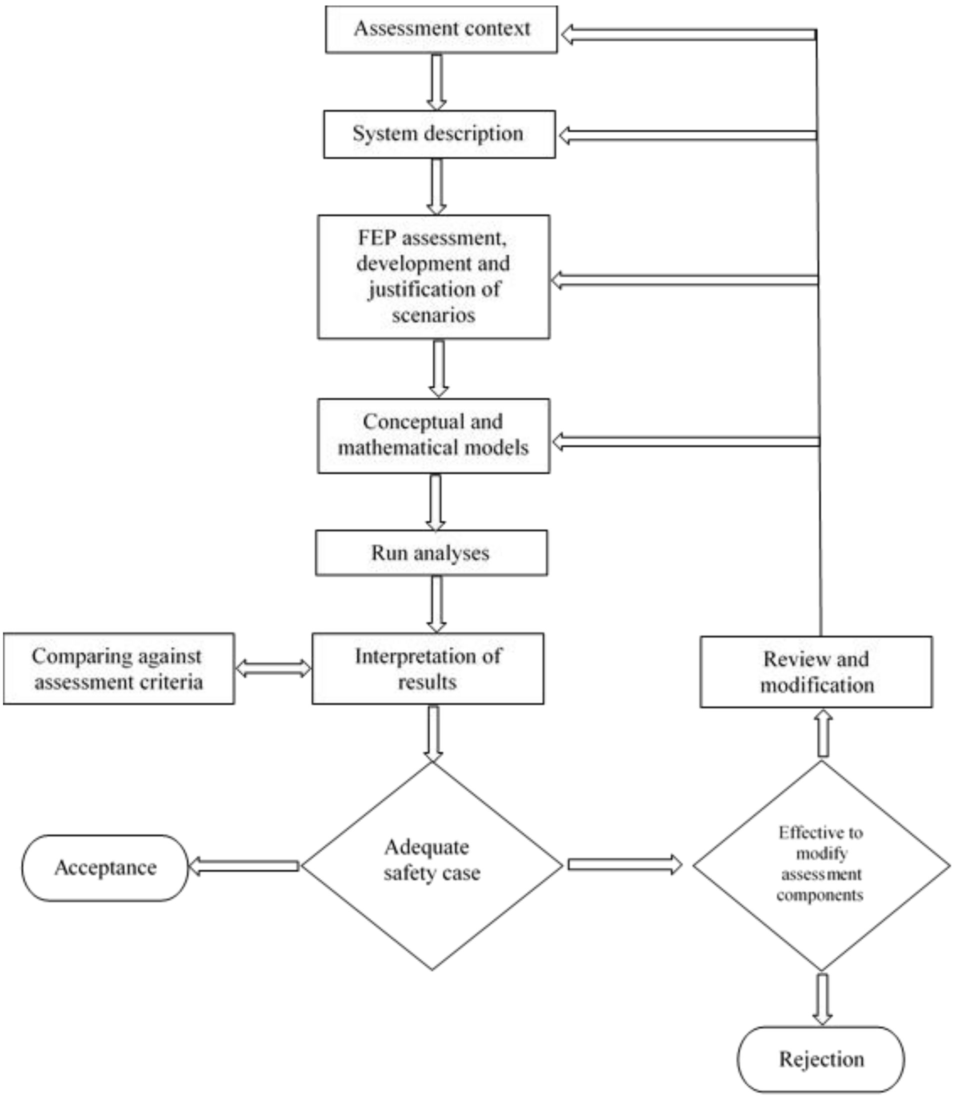
WAC	Properties allowed for packages	Allowed single radionuclides	Total amount of mass or activity of single radionuclides that is allowed to be disposed of at the NRWR.
		Prohibited physical properties	Void space within waste packages >10 % V/V.
			Free liquid content > 1% V/V.
			Compressive strength of solidified wastes > 10-30 N/mm².
		Prohibited hazard properties	Explosive, corrosive, inflammable, caustic and septic material.
WP Emplacement (Public Limited Company for Radioactive waste Management, 2017)	Disposal Vault [1]	ID	I-K1
		WP or disposal module capacity	537 reinforced container disposal unit
	Disposal Vault [2]	ID	I-K2
		WP or disposal module capacity	1 470 compact waste packages, 490 separate drums in the vault, 2 226 separate drums on top of the vault
	Disposal Vault [3]	ID	I-K3
		WP or disposal module capacity	2 436 compact waste packages, 2 829 separate drums on top of the vault
	Disposal Vault [4]	ID	I-K4
		WP or disposal module capacity	1 470 compact waste packages
	Disposal Vault [5]	ID	I-N1
		WP or disposal module capacity	2 688 compact waste packages, 3 174 separate drums on top of the vault
	Disposal Vault [6]	ID	I-N2
		WP or disposal module capacity	2 772 compact waste packages, 3 266 separate rums on top of the vault

Source: NEA, 2019.

Box 4.2: Safety assessment for NRWR repository

The safety assessment procedure supporting the licensing of NRWR is in compliance with the IAEA guidance (IAEA, 2004). The post-closure safety assessment methodology is illustrated in Figure 4.9. The post-closure safety assessment is an iterative process, which incorporates system description, screening of FEPs (Features, Events and Processes), scenario development, setting up of conceptual and mathematical models, running analyses and evaluation of results for different scenarios, uncertainty and sensitivity analysis, and comparing assessment results against regulatory limits.

Figure 4.9: The post-closure safety assessment methodology



Source: NEA, 2019.

5. Controlled dictionaries

5.1. Introduction to controlled dictionaries and their place in RepMet

Controlled dictionaries (also called *controlled vocabularies*) are collections of agreed terms that a community or an organisation uses, manages and maintains in a controlled way within a particular domain of interest. They play a fundamental role in harmonisation of data and information systems, supporting system interoperability and long-term usability. On the data provider side, controlled dictionaries help the development of uniform content, whereas, on the data user side, they support queries and understanding. Modern controlled dictionaries are often implemented using the technologies and standards of the World Wide Web, such as the international standards that the World Web Consortium (W3C) has developed.

The design of a CDM such as that presented in Chapter 3. requires a special effort on the definition of the meaning of the entities such as repository requirements and structures in the Repository Library. The entities need consistent, clear and unambiguous definitions to allow the appropriate selection of relationships and cardinalities in the ERD. This formal definition of the semantics of the domain is an essential step in the design of a database or information system, and the controlled dictionary is therefore a fundamental tool for the long-term management of information, data and knowledge inside a Radioactive Waste Management Organisation (RWMO).

The three RepMet Libraries include controlled dictionaries developed with the RDF/SKOS standard originating with W3C. Chapter 3 of the "RepMet Tools and Guidelines" report (NEA, 2021c) provides an introduction to controlled dictionaries, why they are useful and the technical bases underlying them, with examples from the domain of RepMet.

The RepMet team has developed a RDF/SKOS controlled dictionary for the attributes of each entity in the Repository Library CDM (Figure 3.1). These are outputs of the RepMet initiative that RWMOs can reuse and extend further.

This chapter illustrates how the RepMet team developed the set of controlled dictionaries in the Repository Library, and sets out the benefits for RWMOs in their implementation and use.

5.2. Methodology

The RepMet team developed the RDF/SKOS controlled dictionaries for the attributes of each CDM entity in the Repository Library following four successive steps. They are:

Step 1. Analysis of multiple information sources to select attributes for each entity;

Step 2. Arrangement of the selected attributes in mind-map[9] format for each entity;

Step 3. Identification of relevant information for each attribute:

-*Definition*: a clear and unambiguous definition of the attribute;

-*Definition source*: the authoritative source of the attribute definition;

9. Mind-maps are diagrams showing relationships between concepts in an effective visual way.

-*Purpose*: the general reason justifying the collection of data about the attribute;

-*Comment*: an optional general comment about the attribute;

Step 4. Conversion of the resulting controlled dictionaries into the RDF/SKOS format as reported in Section 3.4 of "RepMet Tools and Guidelines" (NEA, 2021c).

The following sections provide further details for each step.

5.2.1. Step 1 – Information sources

The RepMet group selected the attributes for the entities of the Repository Library after a thorough investigation of available information sources:

- public documents that relevant organisations that were not part of the RepMet initiative published about waste management;
- any additional documentation of the RWMOs and research laboratories.

5.2.2. Step 2 – Mind-map

The outputs of Step 1 are the lists of attributes for each entity of the Repository Library CDMs. In Step 2, the attributes of each entity were arranged in a mind-map structure. In fact, the RepMet group used the mind-map as a way to define and represent graphically the hierarchical organisation of the attribute lists identified for each entity. Figure 5.1 illustrates the mind-map associated with the "R-EBS" entity.

5.2.3. Step 3 – Attribute features

Step 3 comprised the identification of additional features for each attribute in the mind-map, as illustrated in Table 5.1.

Table 5.1: Features for attributes in the mind-map

Features	Meaning
Definition	A clear and unambiguous definition of the attribute
Definition source	The authoritative source of the attribute definition
Purpose	General reason justifying the collection of data about the attribute
Comment	Optional general comment

Source: NEA, 2019.

The reason for collecting data about an attribute (expressed in the "Purpose" feature) depends on the type of attribute, the context of the database and, of course, the special needs of a particular national RWMO. For the Repository Library, leaving aside the special national requirements, it is clear that the reason for considering an attribute is mainly related to the post-closure safety. That means that a controlled dictionary designed in this way can support the development of safety cases (e.g. post-closure safety case for a repository).

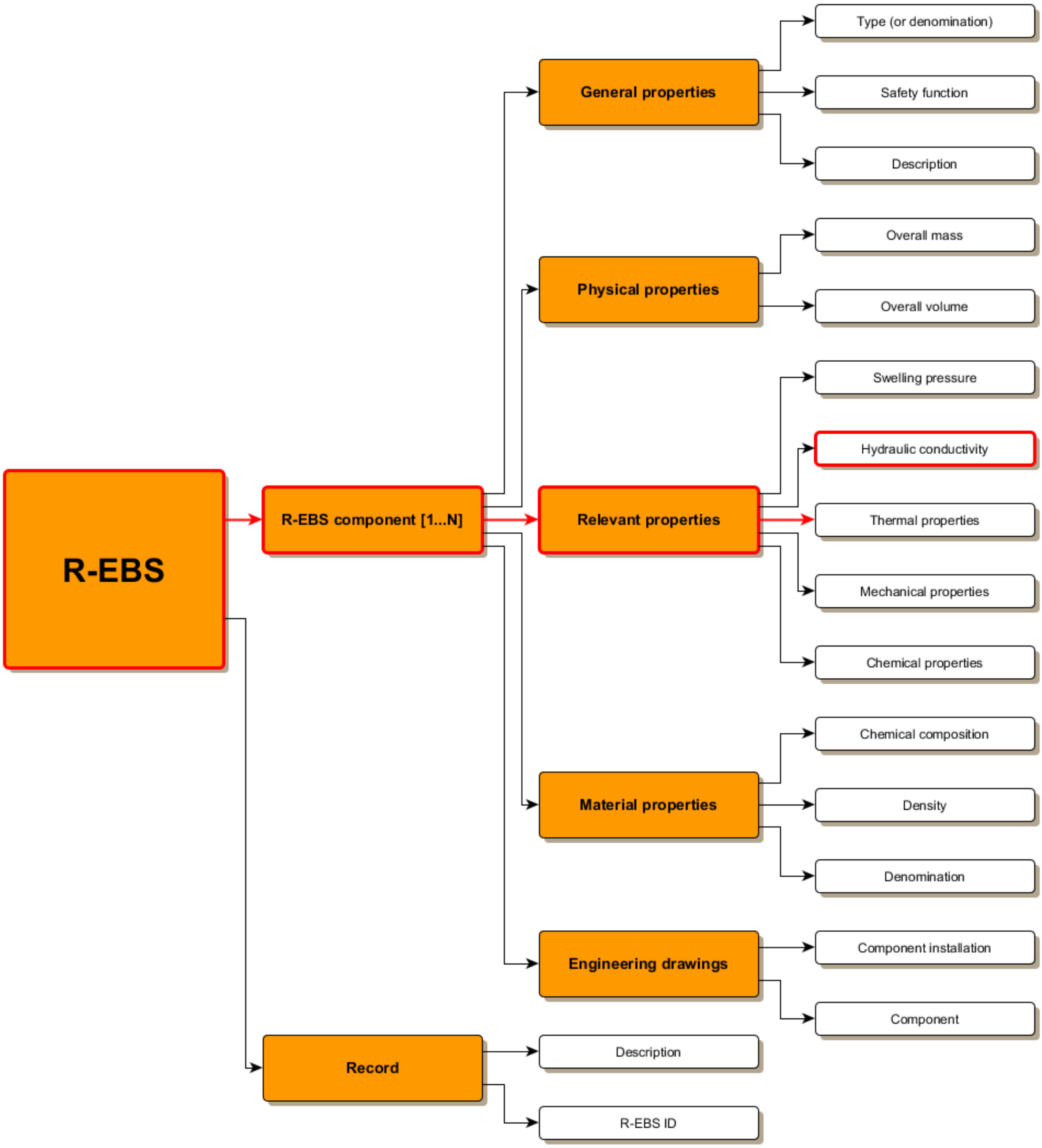
As an example, "hydraulic conductivity" is an attribute of the "R-EBS" entity in the library. Table 5.2. shows the value that the RepMet group identified for the features of the "hydraulic conductivity" attribute.

Table 5.2: Features of the "hydraulic conductivity" attribute

Features	Meaning
Definition	Coefficient relating the water flow velocity to the hydraulic gradient under laminar flow condition.
Definition source	-
Purpose	The lower the hydraulic conductivity is, the more the advective transport through the media (i.e. the buffer) is limited (safety function).
Comment	Darcy's law.

Source: NEA, 2019.

Figure 5.1: Controlled dictionary for "R-EBS" – Mind-map visualisation



Source: NEA, 2019.

5.2.4. Step 4 – RDF/SKOS Conversion

Step 4 comprises the implementation of the RDF/SKOS format for the controlled dictionaries resulting from the first three steps, as explained in Section 3.4 of "RepMet Tools and Guidelines" (NEA, 2021c). This means that each attribute was considered as a SKOS concept (a particular type of RDF resource) and its features were converted into

RDF predicates describing the properties of the resource according to the SKOS vocabulary for RDF.

Table 5.3 shows how the attribute features are converted into RDF triples composed of subject (i.e. the "hydraulic conductivity" resource-attribute), predicates according to the SKOS vocabulary, and objects.

Table 5.3: "Hydraulic conductivity" RDF triples[10]

"Hydraulic conductivity" - RDF triples		
Subject	**Predicate**	**Object**
https://www.oecd-nea.org/rwm/igsc/repmet/Waste/n53	skos:inScheme	https://www.oecd-nea.org/rwm/igsc/repmet/Repository/n0 ("R-EBS" resource)
	skos:broader	https://www.oecd-nea.org/rwm/igsc/repmet/Repository/n26 ("Relevant properties" resource)
	skos:prefLabel	Hydraulic conductivity @en
	skos:definition	Coefficient relating the water flow velocity to the hydraulic gradient under laminar flow condition.
	dc:source	-
	skos:scopeNote	The lower the hydraulic conductivity is, the more the advective transport through the media (i.e. the buffer) is limited (safety function).
	skos:comment	Darcy's law.

Source: NEA, 2019.

Examining Table 5.3 row by row, the "hydraulic conductivity" attribute which is the SKOS concept "rpm:Waste/n53"[11] has the following features:

- It belongs to the SKOS concept scheme identified as "rpm:Repository/n0" (i.e. the "R-EBS" entity);
- It has a broader SKOS concept available identified as "rpm:Repository/n26" (i.e. the "Relevant properties");
- It has as preferred label in English "Hydraulic conductivity";
- It is defined as "Coefficient relating the water flow velocity to the hydraulic gradient under laminar flow condition";
- It has to be taken into account by the RWMOs for the post-closure safety case development since "the lower the hydraulic conductivity is, the more the advective transport through the media (i.e. the buffer) is limited (safety function)";

10. The URLs provided in Table 5.3, Table 5.4 and Figure 5.2 are provided as examples only and do not currently link to any live resources.

11. "rpm:" is a namespace standing for "www.oecd-nea.org\\rwm\\igsc\\repmet\\".

- There is a comment that it is related to the “Darcy’s law”.

The set of RDF triples describing each resource (i.e. each attribute of Repository Library) are available online on the NEA website in both human-readable (i.e. HTML) and machine-readable (i.e. XML serialisation) formats.

Table 5.4 and Figure 5.2 illustrate the two mentioned formats for the “hydraulic conductivity” attribute:

- The first shows an HTML table illustrating in human-readable format the features of the resource.
- The second presents an XML serialisation to encode the resource features in a way that can be managed by a RDF Management System such as server application.

Table 5.4: Hydraulic conductivity” RDF description – Human-readable format (HTML)

ID	http://www.oecd-nea.org/repmet/Repository/n53
RDF Type	http://www.w3.org/2004/02/skos/core#Concept
Broader term	Relevant properties
Name	Hydraulic conductivity
Definition	Coefficient relating the water flow velocity to the hydraulic gradient under laminar flow condition.
Comment	Darcy’s law.
Definition source	-
Purpose	The lower the hydraulic conductivity is, the more the advective transport through the media (i.e. the buffer) is limited (safety function).

Source: NEA, 2019.

Figure 5.2: “Hydraulic conductivity” RDF description – Machine-readable format (XML serialisation)

“Hydraulic conductivity” RDF description – Machine-readable format (XML serialisation)


```
<rdf:RDF
  xmlns:dc="http://purl.org/dc/elements/1.1/"
  xmlns:skos="http://www.w3.org/2004/02/skos/core#"
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:rpm="https://www.oecd-nea.org/rwm/igsc/repmet/">

  <rdf:Description rdf:about="https://www.oecd-nea.org/rwm/igsc/repmet/Waste/n53">
    <skos:inScheme rdf:resource="https://www.oecd-nea.org/rwm/igsc/repmet/Waste/n0"/>
    <skos:broader rdf:resource="https://www.oecd-nea.org/rwm/igsc/repmet/Waste/n26"/>
    <rdf:type rdf:resource="http://www.w3.org/2004/02/skos/core#Concept"/>
    <skos:prefLabel xml:lang="en">Hydraulic conductivity</skos:prefLabel>
    <skos:definition xml:lang="en">
      Coefficient relating the water flow velocity to the hydraulic gradient under laminar flow
      condition
    </skos:definition>
```

```xml
      <dc:source>-</dc:source>
      <rdfs:comment xml:lang="en">
        Darcy's law.
      </rdfs:comment>
      <skos:scopeNote>
        The lower the hydraulic conductivity is, the more the advective transport through the media (i.e.
        the buffer) is limited (safety function).      </skos:scopeNote>
    </rdf:Description>
  </rdf:RDF>
```

Source: NEA, 2019.

5.3. The usable outputs of the work on controlled dictionaries

The usable outputs resulting from the application by the RepMet team of the above methodology can be summarised as follows. They are available online and RWMOs may adopt, extend or develop them further.

- Mind-maps for each entity of the CDMs presented in Figure 3.1 (Repository)

  Format: *HTML*

  Location: *Specific URL, or how to locate them (e.g. top-level web page with links to follow)*

- Controlled dictionaries formalising the mind-maps and suitable for automated processing

  Format: *HTML and XML serialising the RDF/SKOS format*

  Location: *Specific URL, or how to locate them (e.g. top-level web page with links to follow)*

6. Concluding remarks

The Repository Library is a technical product of the Nuclear Energy Agency (NEA) Integration Group for the Safety Case (IGSC) RepMet initiative. It is composed of a report (this document) and an associated technical library dealing with data and related metadata about the requirements and structures of a radioactive waste repository at the time of closure. It is a technical report that has two principal aims:

- To show how the use of appropriate metadata can support the long-term management of the “core information”, that is acquired during the management and operation of a radioactive waste repository at the time of closure;
- To provide application examples about how implementing the metadata-based techniques can support the long-term management of the “core information”.

The library includes high-level conceptual data models, descriptions of data entities, attributes, associated metadata and controlled dictionaries. The library also includes application examples from two existing repositories in the United States and Hungary. Radioactive Waste Management Organisations (RWMOs) can reuse and further extend the models and controlled dictionaries in the development of their own data and information systems, and to help meet the requirements of local and national regulations and of the technologies used at specific repositories.

The controlled dictionaries created for the Repository Library are less detailed than those for the Waste Package Library. This is primarily due to the nature of the Repository Library as a set of data models that connect the Waste Package and the Site Characterisation Libraries. Much data for the Repository Library is derived from the Waste Package and Site Characterisation Libraries which contain more detailed controlled dictionaries.

Prior to the establishment of the RepMet initiative there was a lack of national and international metadata standards that specifically supported the management of radioactive waste. Therefore, the RepMet group reviewed a range of metadata standards, and then selected a number that, even if originally not related or designed for repository management, are based on generic concepts and schemas that can be easily adapted and applied to this field. The selected standards are O&M, MRMS and the W3C RDF/SKOS. Specific standards that support the management of data related to project management and construction are also considered including Building Information Modelling (BIM).

Although the RepMet initiative has now finished, there is further work that can be carried out. This includes the improvement of the controlled dictionaries included in the Repository Library. The controlled dictionaries could then become an international resource provided by the NEA.

Other activities include:

- Further development of the scientific and technical content of the controlled dictionaries (e.g. missing items, and more details for “definition” and “purpose” features for each attribute).

- Definition of a strong connection between the attributes of the controlled dictionaries and the NEA International Features, Events and Processes (IFEP) List included in the NEA FEP Database. This is because each item of the NEA IFEP List reports and explains their eventual relevance for safety assessment.
- Elaboration of controlled dictionaries for attributes of entities in the O&M and MRMS standards.

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