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Waste Package Library

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

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Radioactive Waste Management Committee

Waste Package Library

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

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Table of contents

Tables

Figures

Boxes

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.

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 "Waste Package Library", is the third of these five reports. It supports an associated technical library dealing 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.

The Waste Package Library has two principal aims:

- to identify the "core information" about packaged waste and spent nuclear fuel ready for final disposal, built on the data that the Radioactive Waste Management Organisations (RWMOs) involved in RepMet are currently collecting;
- to provide application examples about how implementing the metadata-based techniques can support the long-term management of the "core information" about packaged waste and spent nuclear fuel ready for final disposal.

Several 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) and SÚRAO (the Czech Republic).

It is hoped that RepMet activities will contribute to easing 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

Andra	Agence nationale pour la gestion des déchets radioactifs (National Radioactive Waste Management Agency, France)
BA	Burnable absorber
BWR	Boiling water reactor
CDM	Conceptual data model
CSD-C	Conteneur Standard de Déchets – Compactés
CSD-V	Conteneur Standard de Déchets – Vitrifiés
Enresa	Empresa Nacional de Residuos Radioactivos S.A. (National Radioactive Waste Company, Spain)
ERD	Entity relationship diagram
GSG	General Safety Guide (IAEA)
HLW	High-level waste
HTMR	Hard to measure radionuclides
IFEP	International Features, Event and Processes (NEA)
IGSC	Integration Group for the Safety Case (NEA)
ILW	Intermediate-level waste
ISO	International Organization for Standardization
JAEA	Japan Atomic Energy Agency
LEWC	Low-enriched waste concentrates
LILW	Low- and intermediate-level waste
LL	Long lived
LLW	Low-level waste
LWR	Light water reactor
MOX	Mixed oxides
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
NWMO	Nuclear Waste Management Organization (Canada)
O&M	ISO standard 19156 "Geographic Information - Observations and Measurements"

OECD	Organisation for Economic Co-operation and Development
OGC	Open Geospatial Consortium
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)
PWR	Pressurised water reactor
RDF	Resource description framework
RepMet	Radioactive Waste Repository Metadata Management (NEA)
RMDC	Recordkeeping Metadata Development Committee
RWM	Radioactive waste management
RWM/NDA	Radioactive Waste Management Ltd. /Nuclear Decommissioning Authority (United Kingdom)
RWMC	Radioactive Waste Management Committee (NEA)
RWMO	Radioactive Waste Management Organisation
SKB	Nuclear Fuel and Waste Management Company (Sweden)
SKOS	Simple Knowledge Organization System
SL	Short lived
SNF	Spent nuclear fuel
SÚRAO	Radioactive Waste Repository Authority (Czech Republic)
UOX	Uranium OXides
URL	Universal Resource Locator
W3C	World Wide Web Consortium
WF	Wasteform
WP	Waste package

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) 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 the Radioactive Waste Repository Metadata Management RepMet has been to formulate a consistent set of guiding principles for capturing and generating metadata. This is 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?

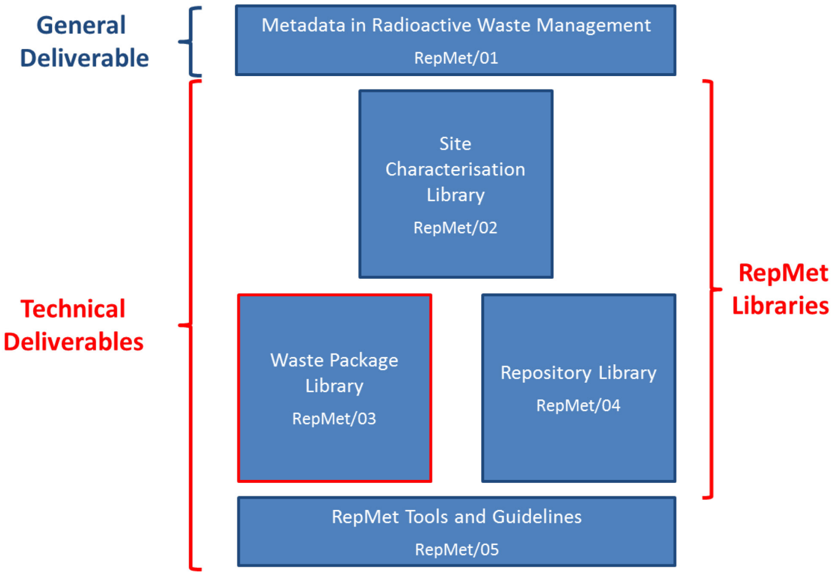
The Radioactive Waste Repository Metadata Management (RepMet) initiative was launched in 2014 by the Integration Group for the Safety Case (IGSC) of the Radioactive Waste Management Committee (RWMC) at the Nuclear Energy Agency (NEA). RepMet analysed and investigated the application of metadata, a fundamental 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 (the 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" (this document) 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" (NEA, 2021b) 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; • Identification of possible designated communities for metadata use.	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 (cont.)

Deliverable	Primary audience	Secondary audience
RepMet/02 – Site Characterisation Library RepMet/03 – Waste Package Library RepMet/04 – Repository Library	Information Systems Developers: • Reusable 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.

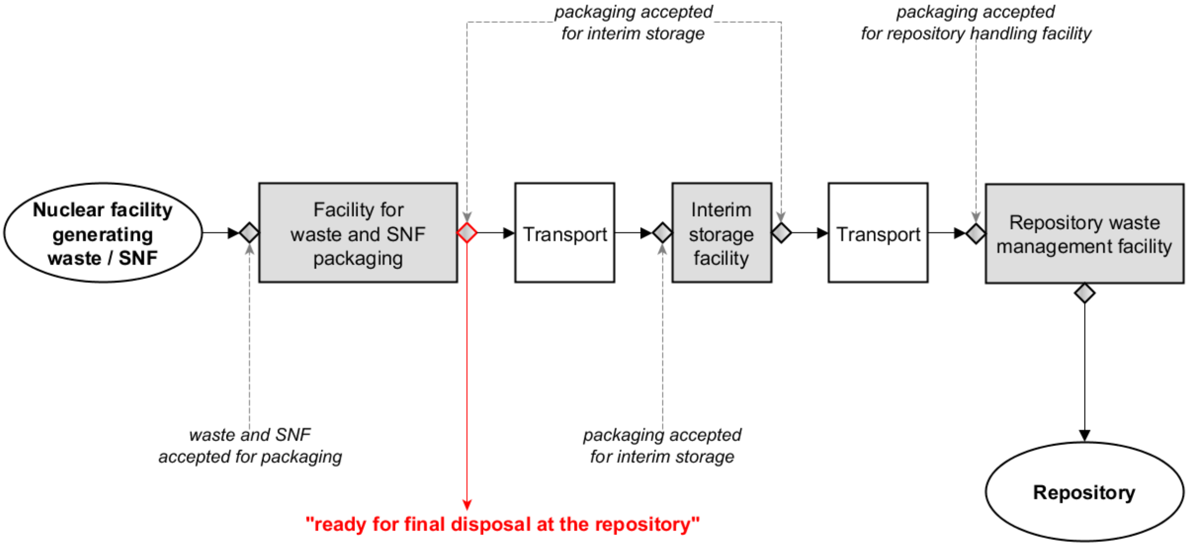
1.3. An introduction to RepMet/03 – Waste Package Library

The Waste Package Library presents a collection of data and metadata models[2] for the description of the "packaged waste and spent nuclear fuel that are ready for disposal in a final repository". The library includes several examples of the application of the data model to real waste packages and disposal systems from the RWMOs involved in the RepMet initiative.

The low-level waste (LLW), the intermediate-level waste (ILW), the high-level waste (HLW) and the Spent Nuclear Fuel (SNF) from commercial light water reactors (LWRs) are all considered in the Waste Package Library. In the RepMet framework, the definition of packaged waste and SNF that is "ready for final disposal" has a well-defined meaning and a precise context. It is the waste or the SNF that is ready to be transported, stored and disposed after the proper treatment and conditioning processes in a dedicated facility. This is illustrated in Figure 1.2, which shows the generic workflow for waste and SNF management that has been assumed within the RepMet framework.

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: Generic workflow for waste and SNF management assumed within the RepMet framework



Source: NEA, 2019.

The Waste Package Library has two principal aims:

- to identify the "core information" about packaged waste and SNF ready for final disposal, built on the data that the RWMOs involved in RepMet are currently collecting; and
- to provide application examples about how implementing the metadata-based techniques that are presented in the "RepMet Tools and Guidelines" report (NEA, 2018) can support the long-term management of the "core information" about packaged waste and SNF ready for final disposal.

This "core information" was produced from the analysis of investigative questionnaires about the data that the RWMOs involved in RepMet are currently collecting. It represents the minimum information that RepMet considers a RWMO should be collecting about packaged waste and SNF ready for final disposal, and the majority of the "core information" is derived from the mandatory information required by regulators from the countries involved in RepMet.[3]

It is not within the scope of RepMet to specify the mandatory information needed for the implementation of a radioactive waste repository, as this depends heavily on specific national requirements. However, what RepMet can do is to show how, through the use of metadata-based techniques of modern data and information management, the access to and confidence in the "core information" can be maintained for current and future generations of users.

3. See Chapter 5. for information about the data sources used.

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

- Chapter 2 introduces the metadata standards that RepMet investigated and used for the development of the Waste Package Library.
- Chapter 3 reports the conceptual data models (CDMs) that RepMet created specifically for the packaged waste and SNF ready for final disposal, along with the CDMs that were obtained from the selected standards.
- Chapter 4 presents real-world application examples of the CDMs introduced in Chapter 3.
- Chapter 5 reports the controlled dictionary containing the "core information" that the RepMet group identified for the packaged waste and SNF ready for final disposal.
- Chapter 6 closes the report and provides considerations for future work.

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

2. Review of existing standards

2.1. Scope

Prior to the establishment of the 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 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.

This Waste Package Library is a technical report designed to show the application of metadata tools and techniques within the field of waste packaging for radioactive waste management. The RepMet group reviewed a range of metadata standards, and then selected a number that, even if originally not related or designed for the waste packaging, are based on generic concepts and schemas that can be easily adapted and applied to this field.[4]

2.2. Metadata standards for the Waste Package Library

RepMet selected, adapted and/or used the following standards for the implementation of the Waste Package 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.

2.2.1. Observations and Measurements (O&M) standard

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 (CDM) 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 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.

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

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 Waste Package Library, an observation may be the estimation of the mass content of ^{239}Pu (property) of a SNF assembly (feature of interest) resulting in a numeric data expressed in grams (result), obtained through numerical simulations with ORIGEN[5] code (process).

A key element of the O&M standard is that instead of using different data models for different kind of observations, 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[6] 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 a specific controlled dictionary supporting the observable properties of packaged waste and SNF ready for final disposal. This original controlled dictionary has been developed using SKOS and is illustrated in Chapter 5.

2.2.2. Simple Knowledge Organization System (SKOS)

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 Waste Package Library includes a web-based controlled dictionary developed according to the SKOS standard, which details the observable properties of the packaged waste and SNF ready for final disposal. 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 packaged waste and SNF ready for the disposal.

2.2.3. Minnesota Recordkeeping Metadata Standard (MRMS)

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,

5. ORIGEN is a computer code system for calculating the build-up, decay, and processing of radioactive materials.

6. A controlled dictionary (also called a controlled vocabulary) is a collection of agreed terms that a community or an organisation uses, manages and maintains in a controlled way within a particular domain of interest. The terms will refer to entities within the domain and their attributes. All terms in a controlled dictionary have unambiguous and non-redundant identification, and may be connected to each other through clearly defined relationships declaring, for example, that one term is broader than another. There may also be multilingual labels for terms, allowing consistent usage in different languages.

releasing version 1.3 of MRMS in 2015. It shares many of its elements with other metadata standards, such as the Dublin Core[7] and ISO 19115.[8] 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.

7. 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.)

8. 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:-1:ed-1:v1:en).

3. Conceptual data models (CDMs)

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 radioactive waste and SNF in the case of the Waste Package 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 Waste Package Library, the Radioactive Waste Repository Metadata Management (RepMet) initiative created an original CDM to structure and organise the data about the packaged and SNF ready for final disposal. This CDM is an original product of the RepMet initiative and is not included in any of the selected standards reported in Chapter 2. However, the Waste Package Library also relies on CDMs from the MRMS and O&M standard. Items of data related to the attributes of the Waste Package Library CDM are supported by items of metadata coming from these standards and arranged in analogous CDMs. The CDM is the backbone of the Waste Package Library. Within the CDM:

- Entities are "*real-world*" objects related to packaged waste and SNF ready for final disposal. Each entity is associated to a list of attributes that constitute the basic elements of the identified core information about packaged waste and SNF.
- 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 Waste Package Library is well defined and is suitable for customisation and implementation by RWMOs within a data storage system, although 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. Waste Package Library CDM

The Waste Package 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 Waste Package Library CDM is composed of 11 entities – see Figure 3.2. Some come from the high-level categories of the 2nd RepMet questionnaire on low and intermediate-level (LILW) waste packages (see Section 5.2.1), and the remaining entities have been added after looking at the international packaged waste disposal systems in order to include the packaged HLW and the SNF.

These entities and their definitions are reported in Table 3.1. IAEA definitions (IAEA, 2007) have been used as the 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 so that it can meet the needs of the diverse range of packaging solutions adopted by RWMOs and can be adapted for their own specific waste and disposal solutions.

Note that a number of the entities within Table 3.1, for example the *disposal container*, are optional and do not need to be used if not required.

Figure 3.1. illustrates the conceptual structure for the packaged waste and SNF described by the RepMet CDM. In the figure each box corresponds to an entity with all the boxes placed one inside another like Russian Matryoshka dolls.

The *wasteform*, the *waste package* and the *disposal module* are “composite entities”. These are indicated in red in Figure 3.1. Each of these composite entities is a *logical unit*, which includes everything physically contained within it. In particular:

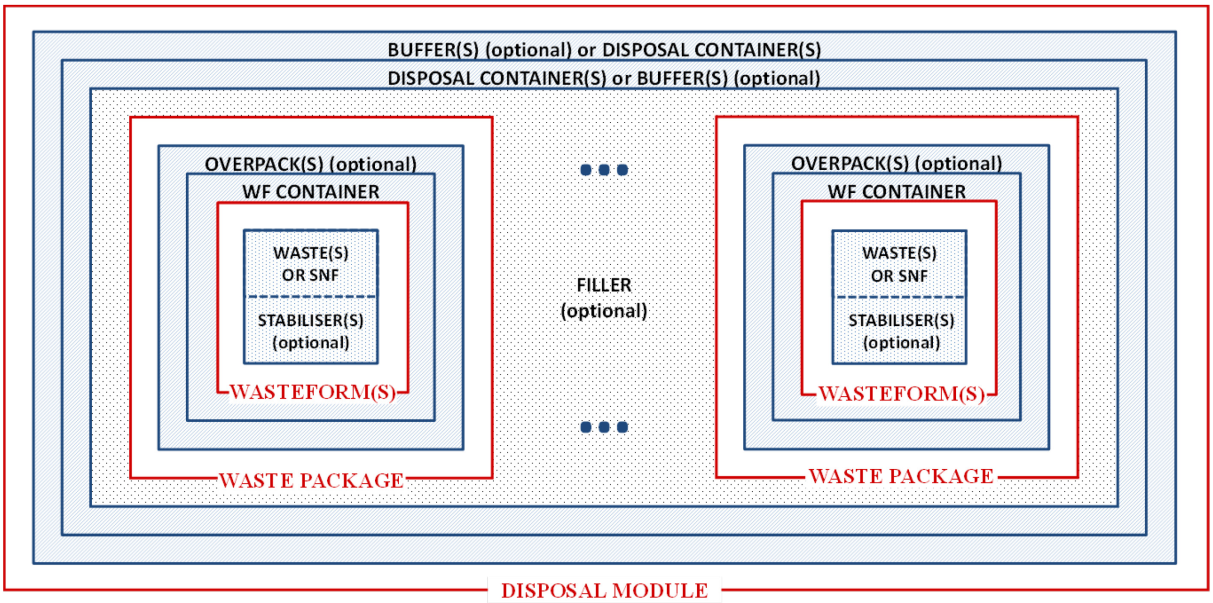
- The *wasteform* describes all the contents of a *wasteform container* (even if there are multiple *wastes*, *spent nuclear fuel* or *stabilisers* within);
- The *waste package* describes the *wasteform container*, the *overpack* and all its contents; and
- The *disposal module* describes the *disposal container* and all its contents (even if there are multiple types of *waste package* within).

The definitions in Table 3.1 imply that there is a special case when a *wasteform container* is placed into a single outer vessel without a *filler* or *buffer* material. In this case the outer vessel may be referred to as either an *overpack* or a *waste package container*. In this case:

- If it is LILW, the preferred term is *overpack*;
- If it is HLW or SNF, the preferred term is *disposal container*;

- If more than one *wasteform container* is placed within a vessel, or if there is a filler material in-between, the term would always be *disposal container*.

Figure 3.1: Conceptual picture of packaged waste and SNF ready for final disposal



Source: NEA, 2019.

3.2.2. Attributes

Each entity has an associated set of attributes that were assembled from a number of sources. For example, questionnaires provided to the RepMet RWMOs and public documents available online. See Chapter 5 for more information on the RepMet work in developing the attributes of the Waste Package 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 3.2. Cardinalities are explained in more detail in Chapter 2 of the "RepMet Tools and Guidelines" report (NEA, 2021c).

Table 3.1: Waste Package Library CDM - Entity Definitions

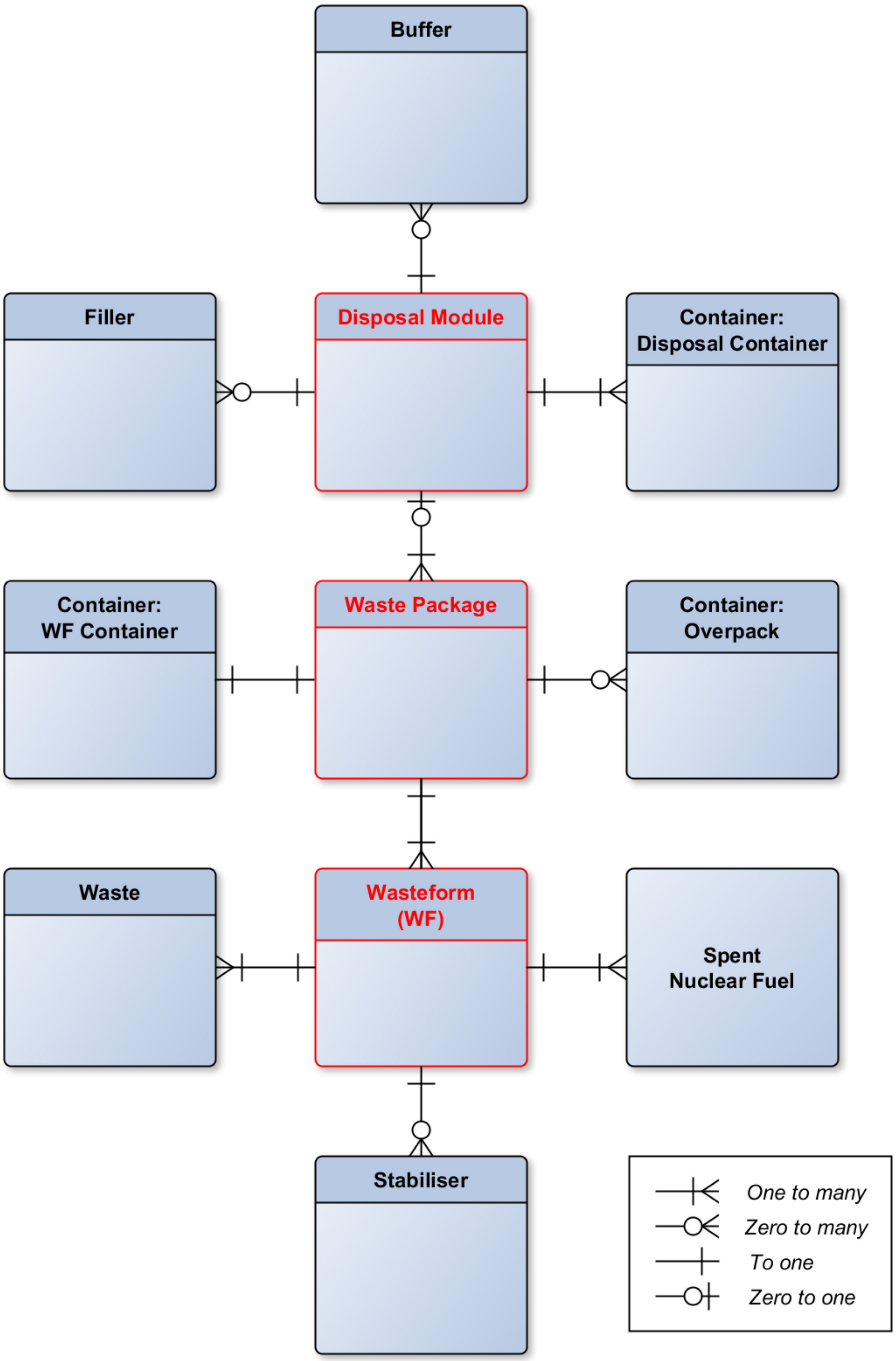
Entity	Definition
buffer	additional material or mix of materials that contributes to prevent or reduce the migration of radionuclides from the **disposal module**
container	vessel into which items are placed. Note: examples of containers are the **wasteform container**, the **overpack** and the **disposal container**
disposal container	container into which one or more **waste packages**, and optional **filler(s)** or **buffer(s)**, may be placed
disposal module	ensemble of one or more **waste packages** together with their **disposal container(s)**, optional **filler(s)** and **buffer(s)**, suitable for handling, transport, storage and disposal
filler	material or a mix of materials that is added to the **disposal container** filling the void spaces
overpack	container into which the **wasteform container** may be placed
stabiliser	material or mix of materials that is used in treatment and conditioning process to stabilise, either physically and/or chemically, one or more **waste(s)**, or one or more **spent nuclear fuel**, to give a **wasteform**
spent nuclear fuel, SNF	nuclear fuel removed from a reactor following irradiation that is no longer usable in its present form
waste	raw material in gaseous, liquid or solid form that is intended for storage and disposal after proper treatment and conditioning Note: waste materials conditioned into containers that are considered unfit[9] for disposal are also waste, as they require further treatment before disposal.
waste package, WP	ensemble of one or more **wasteforms** together with their **wasteform container** and optional **overpack(s)**, suitable for handling, transport, storage and/or disposal
wasteform, WF	**waste**, or **spent nuclear fuel**, in the physically and chemically stable form in which it will be disposed of, including any **stabilisers** and container furniture[10], but not including the **wasteform container**
wasteform container	container into which one or more **wasteforms** are made or placed

Source: NEA, 2019.

9. For example, legacy waste packages that cannot disposed of according to the current policies and practices; drums to be super-compacted and then inserted in a bigger container for volume reduction; etc.

10. For example, dewatering tubes and in-drum mixing puddles.

Figure 3.2: Waste Package Library CDM – Entity-Relationship Diagram



Source: NEA, 2019.

3.3. Spent Nuclear Fuel CDM

Spent Nuclear Fuel is one of the most challenging objects to document prior to its disposal in a final repository. Large volumes of data and information are required to assure a safe and secure management of the SNF up to the final disposal, regarding both the physical assemblies and their irradiation history in the reactor.

For this reason, RepMet developed the SNF entity, with a dedicated CDM detailed in Figure 3.3. The SNF entity can be considered to be a "*macro-entity*" of the Waste Package Library CDM, and which is detailed in a dedicated sub-CDM – the "*Spent Nuclear Fuel CDM*".

3.3.1. Entities and relationships

The SNF CDM was developed specifically for Light Water Reactor (LWR) nuclear fuel: Pressurised Water Reactors (PWRs) as well as Boiling Water Reactors (BWRs) were considered as part of this.

There are some differences between the fuel assemblies for PWRs and BWRs that need to be considered in the CDM. In a BWR the fuel elements, or fuel rods, are placed in a fuel box, and there are water channels within the array of fuel rods. Neither fuel box nor water channels exist in PWR assemblies. In a PWR assembly, there are special tubes for control rods and instrumentation. The control rods are assembled into a control-rod cluster. These tubes and control-rod clusters do not exist in a BWR. Regarding handling and disposal it should be pointed out that the fuel boxes, as well as the control-rod clusters, can be handled together with the assemblies or be separated from the assemblies and handled in their own, or another waste stream. Even though there are many differences between BWR and PWR assemblies, they can be regarded as being similar in the sense that they both have a rod-array and a set of structural parts ensuring their safe operation and handling. Further, their nuclear design is determined from the geometrical arrangements and lengths of the fuel rods and the composition, e.g. the enrichment, of the pellets they contain.

Figure 3.3 shows the developed CDM for LWR fuel assemblies as an ERD. It is composed of 19 entities that are defined in Table 3.2.

3.3.2. Attributes

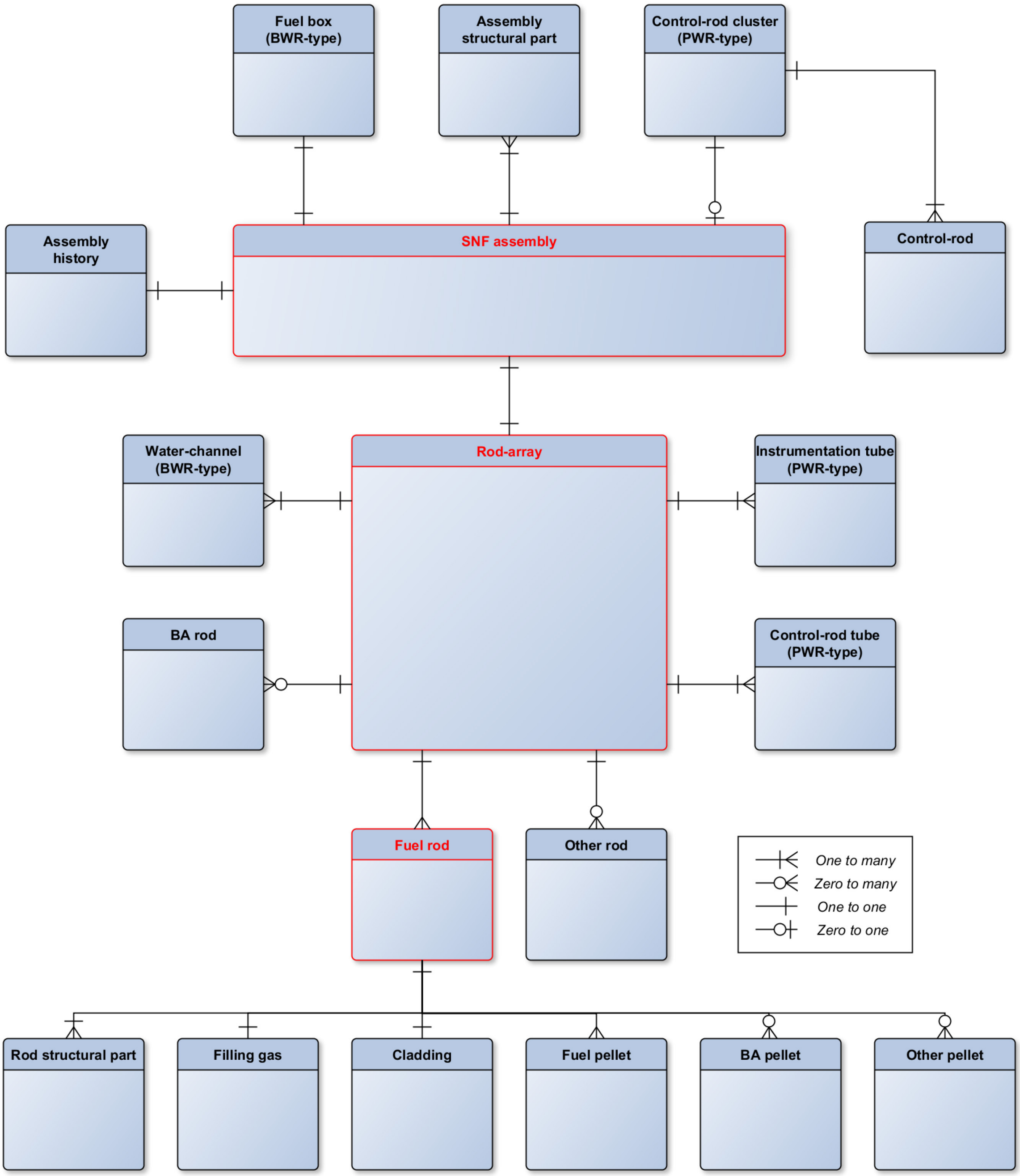
Each entity has an associated set of attributes that were assembled from a number of sources. For example, questionnaires provided to the RepMet RWMOs and public documents available online. See Chapter 5. for more information on the RepMet work in developing the attributes of the SNF CDM.

Table 3.2: Spent Nuclear Fuel CDM – Entity definitions

Entity	Definition
assembly history	record of all the administrative, handling, transport and irradiation operations that involved the **spent nuclear fuel assembly**
assembly structural part	features of the **spent nuclear fuel assembly** at final discharge from the reactor necessary for its handling, storage and final disposal
burnable absorber pellet, BA pellet	nuclear **fuel pellet** containing burnable absorber
Cladding	closed shell for nuclear fuel intended to prevent chemical reactions between nuclear fuel and cooling agent, to contain radioactive substances formed during the irradiation and to support the nuclear fuel
control-rod	rod shaped reactor component that directly impact the reactivity and is used for reactor control Note: The cross section can for example be round or cross-shaped
control-rod cluster	assembly of round **control rods** operated commonly Note: Used in PWR reactors, and can be handled jointly with a PWR fuel assembly
control-rod tube	tube for **control-rod** within the **rod-array** of a PWR fuel assembly
instrumentation tube	tube for instrumentation within the **rod-array** of a PWR fuel assembly
filling gas	gas enclosed in the **cladding** that fill the space between the **fuel pellets** and **cladding** prior to irradiation
fuel rod	rod shaped structural part that contains nuclear fuel as its most important component and that is intended to be used in a nuclear reactor
fuel box	casing with quadratic cross section holding a **fuel rod-array** and circumscribing its hole or tube through the moderator, and through which the cooling agent can circulate Note: used in BWR reactors, and can be handled jointly with a BWR fuel assembly
fuel pellet	fuel body in shape of a short cylinder that is stacked in a **cladding** to form a **fuel rod**
other rod	rod in the **rod-array** not containing nuclear fuel Note: other rods can be filled with other pellets or solid.
other pellet	body in shape of a short cylinder that is stacked in a **cladding** to form an **other rod**
rod-array	cluster of **fuel rods**, and possibly **other rods**, channels or tubes, usually arranged in parallel within a quadratic cross section
rod structural part	features of the **fuel rod** necessary for its handling, storage and final disposal
spent nuclear fuel assembly, SNF assembly	nuclear fuel assembly that has been finally discharged from a reactor and that is not intended to be reused or reprocessed
water channel	structural part intended to distribute the moderator and cooling agent within the **rod-array** of BWR fuel assemblies

Source: NEA, 2019.

Figure 3.3: Spent Nuclear Fuel CDM – Entity-Relationship Diagram



Source: NEA, 2019.

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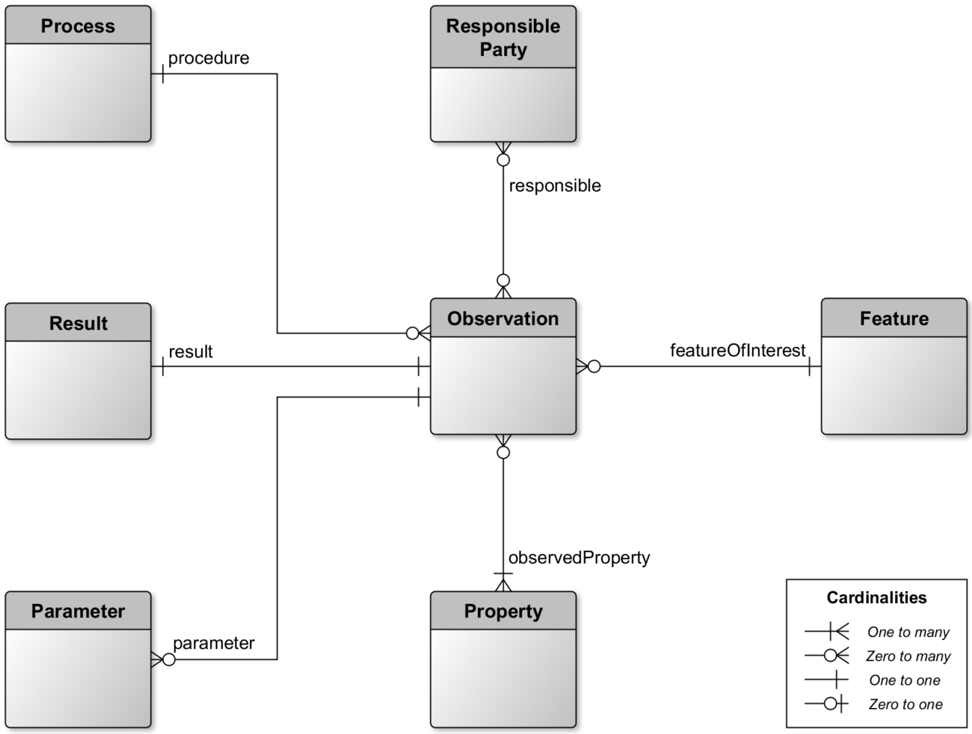
3.4. CDMs from the O&M standard and MRMS

O&M and MRMS are metadata standards that RepMet included in the design of the CDM for the Waste Package 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 Waste Package Library (Figure 3.2) and SNF (Figure 3.3) CDMs. Figure 3.4 illustrates the CDM of the O&M standard.

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

Figure 3.4: Observation and Measurement 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 3.5 illustrates the CDM of the O&M standard including the extension for the sampling features.

Figure 3.5: Observation and Measurement CDM with Sampling Feature extension

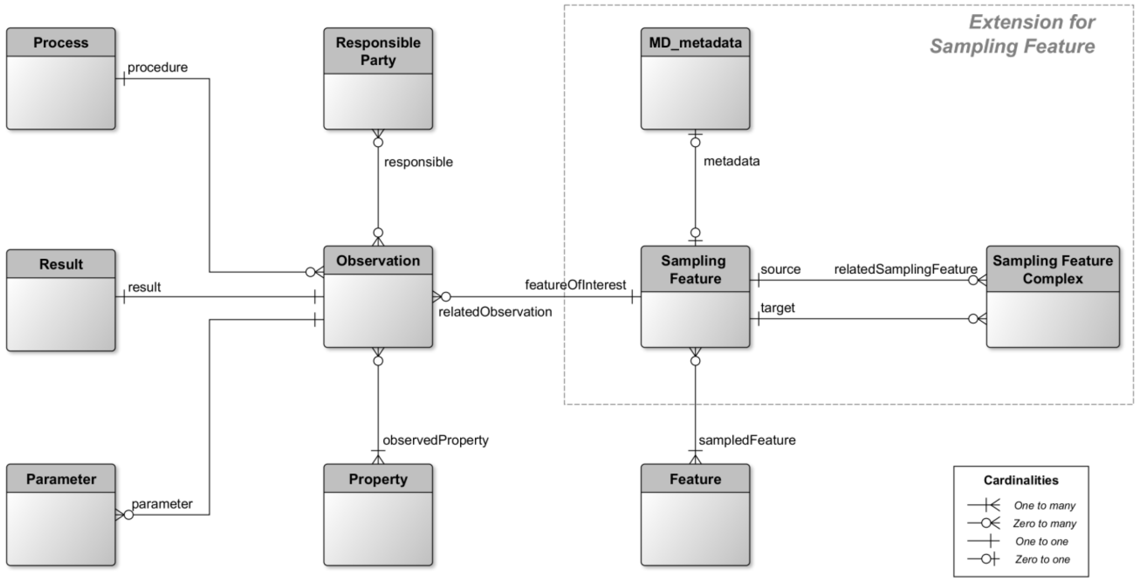
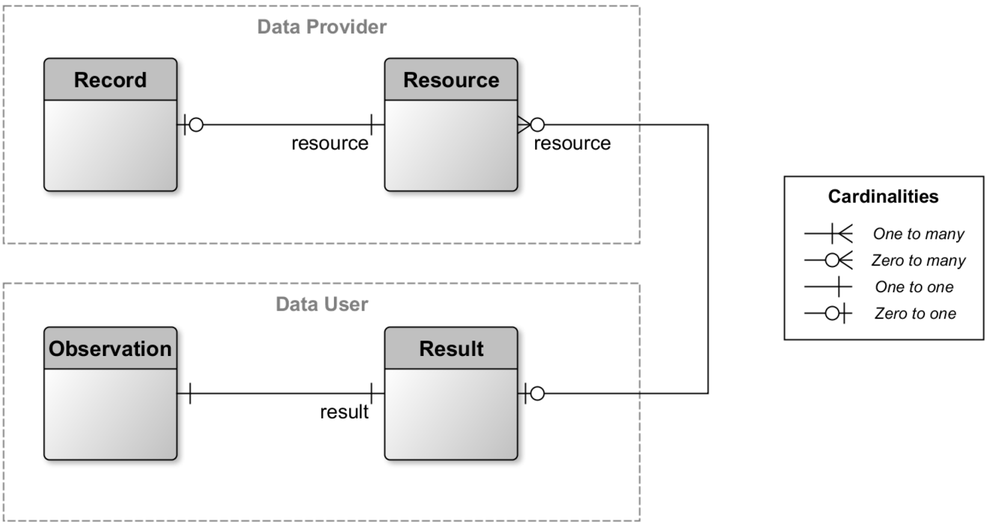


Figure 3.6 illustrates how the MRMS can be interpreted in a CDM and integrated with the O&M CDM.

Source: NEA, 2019.

Figure 3.6: Minnesota Recordkeeping Metadata Standard CDM - Entity Relationship Diagram

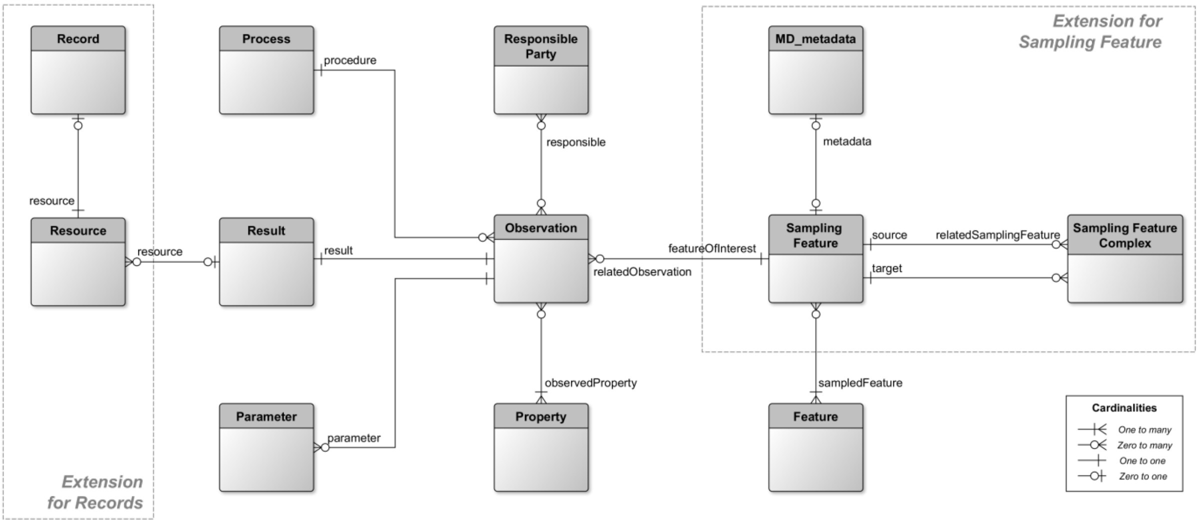


Source: NEA, 2019.

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, whilst the *Record* is the set of administrative metadata elements and the reference to the Resource that is the subject of record-keeping.

Figure 3.7 illustrates the O&M CDM including the sampling feature extension and the integration with the MRMS CDM.

Figure 3.7: O&M Standard with Sampling Feature extension and MRMS in integrated CDM form



Source: NEA, 2019.

The attributes for the entities in Figure 3.4, Figure 3.5 and Figure 3.6 are described in the "RepMet Tools and Guidelines" report (NEA, 2021c).

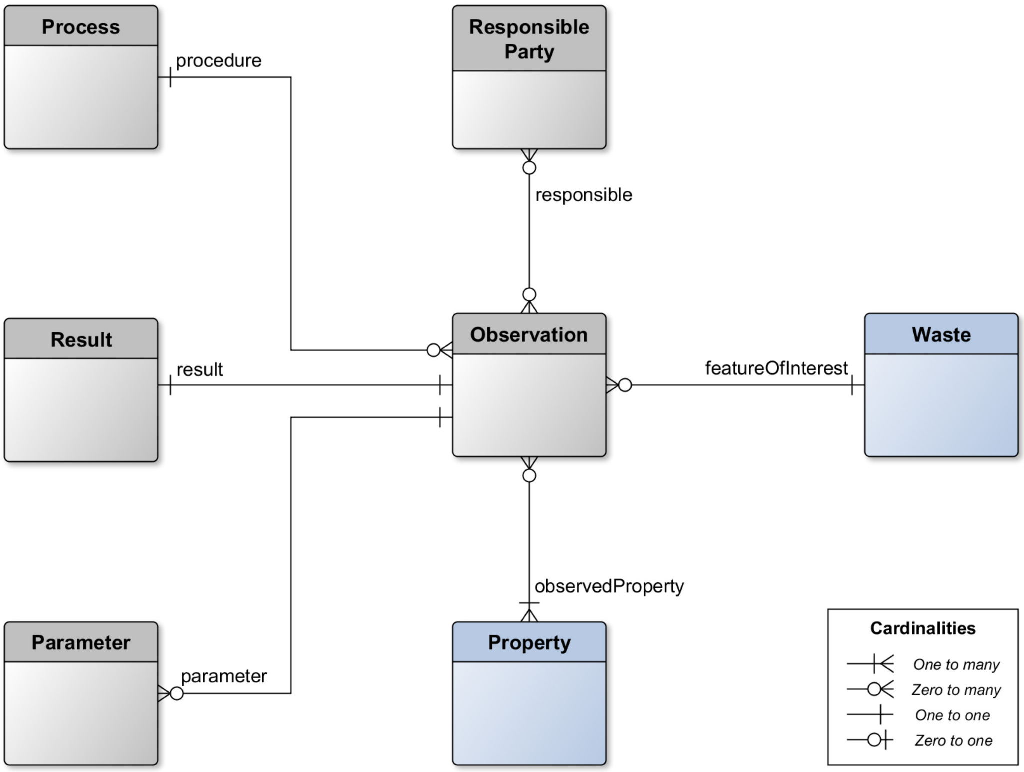
3.5. Connection between Waste Package Library and O&M CDMs

The implementation of the O&M standard and the MRMS in the conceptual design for the database to support packaged waste and SNF 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 for the packaged waste and SNF can be supported and integrated with the CDMs of the selected metadata standards.

- The entities of the Waste Package Library CDM (Figure 3.2) and the SNF CDM (Figure 3.3) 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 wasteform, container, fuel rod or rod-array, that are estimated during an observation process, where the type of observation depends on the type of attribute.

Figure 3.8 illustrates this excluding for simplicity the extension for sampling features and records management (i.e. considering only direct observations for the properties of the feature of interest).

Figure 3.8: Integration of the Waste Package Library CDM with the O&M CDM



Source: NEA, 2019.

Figure 3.8 illustrates the linkage between Waste entity and an associated observation. All the other entities within the Waste Package Library 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 a waste package or an abstract object as an observation.

This chapter provides examples of how the CDMs presented in Chapter 3 can be applied in practice or, through presenting specific instances of CDMs for real-world objects.

4.1. Example applications of the Waste Package Library CDM

This chapter illustrates how a number of real-world packaging examples can be mapped to the entities of the Waste Package Library CDM. It uses examples from:

- Belgium, with courtesy of ONDRAF/NIRAS;
- Hungary, with courtesy of PURAM;
- United Kingdom, with courtesy of RWM/NDA;
- United States, with courtesy of the Department of Energy (DOE) Sandia National Laboratories; and
- Sweden, with courtesy of SKB.

The examples help to show how to apply the Waste Package CDM, in order to capture technical and other related details about the waste.

4.1.1. Belgian packaging examples

In Belgium, there are three categories of radioactive wastes: A, B and C. Table 4.1 provides the correspondences between the Belgian categories and the classes of the international classification according to the IAEA General Safety Guide (GSG) 1.

Table 4.1: Comparison between Belgian classification and IAEA GSG-1

<table>
<tr><td colspan="2" rowspan="2"></td><th colspan="3">GSG-1 Classification</th></tr>
<tr><th>LLW</th><th>ILW</th><th>HLW</th></tr>
<tr><th rowspan="2">Belgium categories</th><th>Long lived (LL)</th><td colspan="2">B</td><td rowspan="2">C</td></tr>
<tr><th>Short Lived (SL)</th><td colspan="2">A</td></tr>
</table>

Source: NEA, 2019.

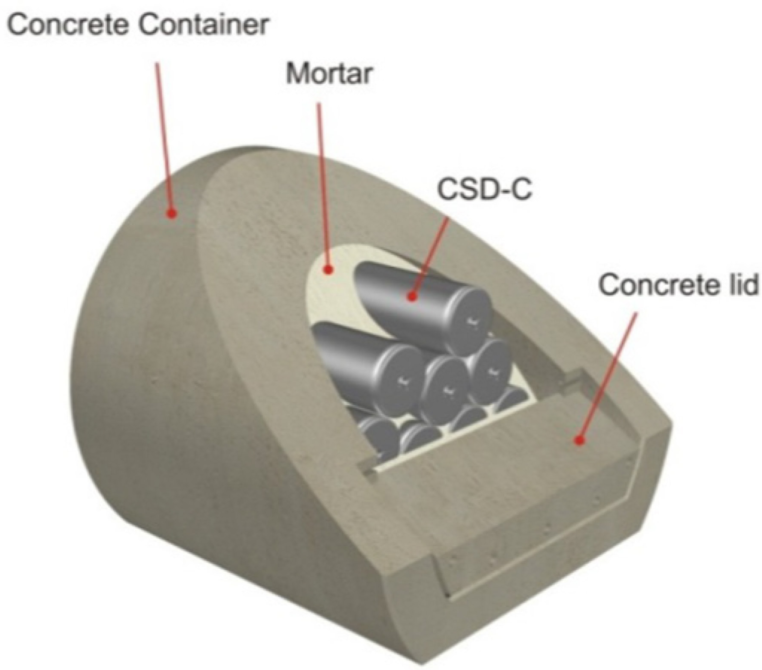
The Belgian Category C includes the vitrified HLW coming from the spent fuel reprocessing and the none-reprocessed SNF. For each category, a different disposal system is provided.

LL-LILW packaging: deep disposal "Monolith"

Figure 4.1 shows the "monolith", the Belgian concept system for the LL-LILW waste disposal in the Boom Clay geological formation. An example of a Belgian LL-LILW packaging is the AREVA CSD-C canister.

The outer concrete container ("caisson") with the mortar and the LL-LILW packages comprise the "monolith" for the disposal in the geological formation.

Figure 4.1: Belgian "Monolith" for LL-LILW (AREVA CSD-C)



Note: the concepts above may be described using the data model given within Figure 3.2 as shown in Table 4.2.
Source: ONDRAF/NIRAS, 2019.

Table 4.2: RepMet CDM applied to Belgian "Monolith" for LL-LILW

Entity				Description
Disposal Module	Waste Package (x8)	WF	Waste	Structural waste (hulls and end-pieces) from SNF reprocessing
			Stabiliser	None
		WF Container		Stainless steel container (AREVA CSD-C)
		Overpack		None
	Disposal Container			Concrete caisson for geological disposal
	Filler			Mortar
	Buffer			None

Source: NEA, 2019.

HLW and SNF packaging: "Supercontainer"

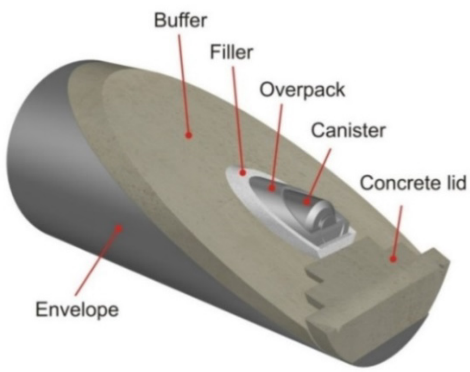
The "supercontainer" is the Belgian concept system for the HLW and the SNF assembly disposal in the Boom Clay geological formation. The typical Belgian HLW packaging is the AREVA CSD-V canister, whereas the typical Belgian SNF is UOX (Uranium OXides) or MOX (Mixed OXides) PWR-type assembly.

The supercontainer is composed of a cylindrical concrete buffer, enveloped in a stainless steel liner, and an overpack containing the HLW or SNF packaging. The space between the HLW packages and the overpack is filled with sand.

Supercontainer for vitrified HLW

Figure 4.2 shows the supercontainer for the disposal of vitrified HLW packages (two per supercontainer).

Figure 4.2: Belgian "Supercontainer" for vitrified HLW (AREVA CSD-V)



Source: ONDRAF/NIRAS, 2019.

The disposal concept for vitrified HLW may be described using the data model given within Figure 3.2 as shown in Table 4.3. In that case, the concrete supercontainer is both disposal container and buffer. Thus, in the library, disposal container and buffer data attributes will describe this real-world object.

Table 4.3: RepMet CDM applied to Belgian "Supercontainer" for vitrified HLW

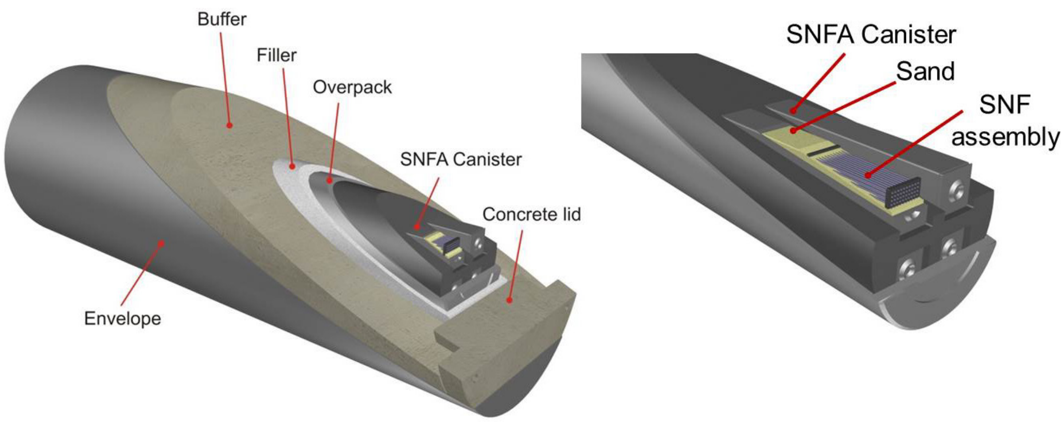
Entity				Description
Disposal Module	Waste Package (x2)	WF	Waste	Liquid waste from SNF reprocessing
			Stabiliser	Borosilicate glass
		WF Container		Stainless steel container (AREVA CSD-V)
		Overpack		None
	Filler (1)			Sand
	Disposal Container (1)			Overpack
	Filler (2)			Filler
	Disposal Container (2)			Concrete Supercontainer
	Buffer			Concrete Supercontainer

Source: NEA, 2019.

Supercontainer for UOX SNF assemblies

Figure 4.3 shows the supercontainer for the disposal of UOX SNF assemblies (four per supercontainer). Each UOX SNF assembly is inserted in a canister ("spent nuclear fuel assembly (SNFA) canister") then filled with sand: four canisters are put in an insert (on the right-hand of Figure 4.3) that, finally, is put in the supercontainer overpack.

Figure 4.3: Belgian "Supercontainer" for UOX SNF assemblies



Source: ONDRAF/NIRAS, 2019.

The disposal concept for the UOX SNF assemblies above may be described using the data model given within Figure 3.2 as shown in Table 4.4. In this case, the concrete supercontainer is both disposal container and buffer. Thus, in the library, disposal container and buffer data attributes will describe this real-world object.

Table 4.4: RepMet CDM applied to Belgian "Supercontainer" for UOX SNF assemblies

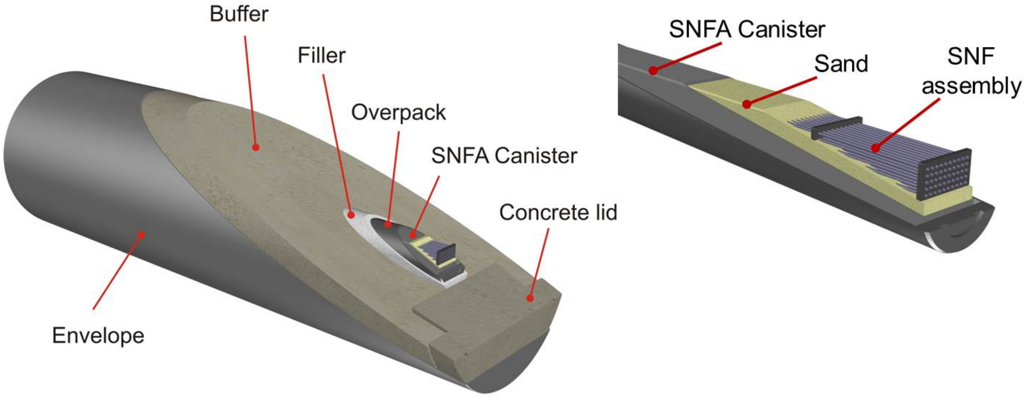
<table>
<tr><th colspan="4">Entity</th><th>Description</th></tr>
<tr><td rowspan="9">Disposal Module</td><td rowspan="4">Waste Package (x4)</td><td rowspan="2">WF</td><td>Waste</td><td>UOX SNF assembly PWR-type</td></tr>
<tr><td>Stabiliser</td><td>Sand</td></tr>
<tr><td colspan="2">WF Container</td><td>SNFA Canister</td></tr>
<tr><td colspan="2">Overpack</td><td>None</td></tr>
<tr><td colspan="3">Filler (1)</td><td>None</td></tr>
<tr><td colspan="3">Disposal Container (1)</td><td>Overpack with insert for SNFA Canister</td></tr>
<tr><td colspan="3">Filler (2)</td><td>Filler</td></tr>
<tr><td colspan="3">Disposal Container (2)</td><td rowspan="2">Concrete Supercontainer</td></tr>
<tr><td colspan="3">Buffer</td></tr>
</table>

Source: NEA, 2019.

Supercontainer for MOX SNF assemblies

Figure 4.4 shows the supercontainer for the disposal of MOX SNF assemblies (one per supercontainer). The MOX SNF assembly is inserted in a canister ("SNFA canister") then filled with sand: one canister is put in a black insert that, finally, is put in the supercontainer overpack.

Figure 4.4: Belgian "Supercontainer" for MOX SNF assembly



Source: ONDRAF/NIRAS, 2019.

The disposal concept for the MOX SNF assemblies above may be described using the data model given within Figure 3.2 as shown Table 4.5. In this case, the concrete supercontainer is both disposal container and buffer. Thus, in the library, disposal container and buffer data attributes will describe this real-world object.

Table 4.5: RepMet CDM applied to Belgian "Supercontainer" for MOX SNF assemblies

<table>
<tr><th colspan="4">Entity</th><th>Description</th></tr>
<tr><td rowspan="9">Disposal Module</td><td rowspan="4">Waste Package</td><td rowspan="2">WF</td><td>Waste</td><td>MOX SNF assembly PWR-type</td></tr>
<tr><td>Stabiliser</td><td>Sand</td></tr>
<tr><td colspan="2">WF Container</td><td>SNFA Canister</td></tr>
<tr><td colspan="2">Overpack</td><td>None</td></tr>
<tr><td colspan="3">Filler (1)</td><td>None</td></tr>
<tr><td colspan="3">Disposal Container (1)</td><td>Overpack with insert for SNFA Canister</td></tr>
<tr><td colspan="3">Filler (2)</td><td>Filler</td></tr>
<tr><td colspan="3">Disposal Container (2)</td><td rowspan="2">Concrete Supercontainer</td></tr>
<tr><td colspan="3">Buffer</td></tr>
</table>

Source: NEA, 2019.

SL-LILW packaging: surface disposal "Monolith"

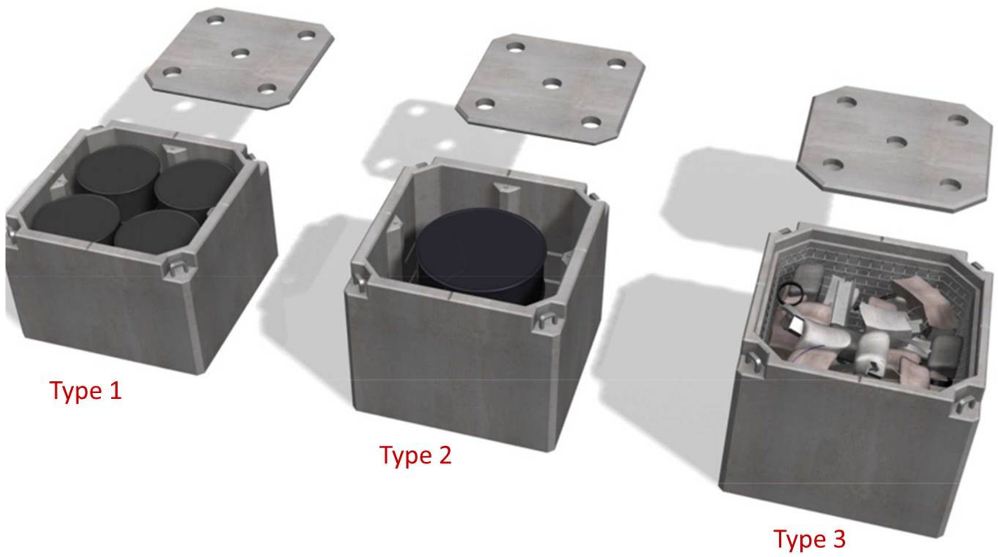
Figure 4.5 shows a different "monolith" for the SL-LILW waste disposal in near-surface facility. ONDRAF/NIRAS, the national Belgian Radioactive Waste Management Organisation (RWMO), developed three types of monolith with identical outer dimensions:

- Type 1 – Is suitable for the disposal of five 220 litre standard drums or four 400 litre standard drums per monolith.
- Type 2 – Is suitable for the disposal of non-standard drums (one single drum per monolith).
- Type 3 – Is used for the disposal of bulk waste, mainly originating from dismantling nuclear facilities. This type is equipped with a steel container to hold the bulk waste.

In the three monolith-types for SL-LILW disposal, the wastes are stabilised in the outer concrete container ("caisson") with mortar in order to have a solid block for disposal.

The concepts above may be described using the data model given within Figure 3.2 as shown in Tables 4.6 to 4.8. Note that the first two example are design concept with no specifications on the waste inventory.

Figure 4.5: Belgian "Monolith" for SL-LILW



Source: ONDRAF/NIRAS, 2019.

Table 4.6: RepMet CDM applied to Belgian "Monolith´ (Type 1) for SL-LILW

<table>
<tr><th colspan="4">Entity</th><th>Description</th></tr>
<tr><td rowspan="7">Disposal Module</td><td rowspan="4">Waste Package (x5 or x4)</td><td rowspan="2">WF</td><td>Waste</td><td rowspan="2">LLW wasteform(s)</td></tr>
<tr><td>Stabiliser</td></tr>
<tr><td colspan="2">WF Container</td><td>220-litre or 400-litre standard drum</td></tr>
<tr><td colspan="2">Overpack</td><td>None</td></tr>
<tr><td colspan="3">Disposal Container</td><td>Concrete caisson for surface disposal</td></tr>
<tr><td colspan="3">Filler</td><td>Mortar</td></tr>
<tr><td colspan="3">Buffer</td><td>None</td></tr>
</table>

Source: NEA, 2019.

Table 4.7: RepMet CDM applied to Belgian “Monolith´ (Type 2) for SL-LILW

<table>
<tr><th colspan="4">Entity</th><th>Description</th></tr>
<tr><td rowspan="7">Disposal Module</td><td rowspan="4">Waste Package</td><td rowspan="2">WF</td><td>Waste</td><td rowspan="2">LLW wasteform(s)</td></tr>
<tr><td>Stabiliser</td></tr>
<tr><td colspan="2">WF Container</td><td>Non-standard drum</td></tr>
<tr><td colspan="2">Overpack</td><td>None</td></tr>
<tr><td colspan="3">Disposal Container</td><td>Concrete caisson for surface disposal</td></tr>
<tr><td colspan="3">Filler</td><td>Mortar</td></tr>
<tr><td colspan="3">Buffer</td><td>None</td></tr>
</table>

Source: NEA, 2019.

Table 4.8: RepMet CDM applied to Belgian “Monolith´ (Type 3) for SL-LILW

<table>
<tr><th colspan="4">Entity</th><th>Description</th></tr>
<tr><td rowspan="7">Disposal Module</td><td rowspan="4">Waste Package</td><td rowspan="2">WF</td><td>Waste</td><td>Bulk wastes</td></tr>
<tr><td>Stabiliser</td><td>Mortar</td></tr>
<tr><td colspan="2">WF Container</td><td>Concrete caisson for surface disposal (included the steel container to hold the bulk waste)</td></tr>
<tr><td colspan="2">Overpack</td><td>None</td></tr>
<tr><td colspan="3">Disposal Container</td><td>None</td></tr>
<tr><td colspan="3">Filler</td><td>None</td></tr>
<tr><td colspan="3">Buffer</td><td>None</td></tr>
</table>

Source: NEA, 2019.

Belgian legacy LILW packaging

Table 4.1 shows that the waste materials conditioned into containers that are considered unfit for disposal are also waste according to the RepMet CDM. For example, containers that are compacted for volume reduction or legacy waste packages that cannot be disposed of nowadays.

SCOMP-CILVA-400

SCOMP-CILVA-400 is a very large waste package family that results from the treatment and conditioning of super-compactable LLWs in the BELGOPROCESS CILVA facility[11].

11. The waste come from the NPPs and various other third parties of the nuclear and non-nuclear sectors. Regular waste producers sort and/or pre-package their non-conditioned, super-

The super-compactable LLWs are initially placed in 220-litre drums. The treatment and conditioning consist of supercompaction of the 220-litre drums by a press, producing a disc. Four discs on average (they varies between one and six) can be piled centrally into a 400-litre standard drum and the void spaces be filled with cement grout. This latter is a SL-LILW according to the Belgian classification, thus they will be disposed of as detailed in Section 4.1.1, and each "monolith" will accommodate four 400-litre standard drums.

This concept can be described using the data model given within Figure 3.2 as shown in Table 4.9.

Table 4.9: RepMet CDM applied to Belgian SCOMP-CILVA-400

<table>
<tr><th colspan="4">Entity</th><th colspan="4">Description</th></tr>
<tr><td rowspan="10">Disposal Module</td><td rowspan="7">Waste Package (x4)</td><td rowspan="5">Wasteform</td><td rowspan="4">Waste (x4 on average)</td><td rowspan="4">WP unfit for final disposal (supercompacted)</td><td rowspan="2">WF</td><td>Waste</td><td>Super-compactable waste</td></tr>
<tr><td>Stabiliser</td><td>None</td></tr>
<tr><td colspan="2">WF Container</td><td>220-litre drum</td></tr>
<tr><td colspan="2">Overpack</td><td>None</td></tr>
<tr><td>Stabiliser</td><td colspan="4">Cement</td></tr>
<tr><td colspan="2">WF Container</td><td colspan="4">400-litre standard drum</td></tr>
<tr><td colspan="2">Overpack</td><td colspan="4">None</td></tr>
<tr><td colspan="3">WP Container</td><td colspan="4">Concrete caisson for surface disposal</td></tr>
<tr><td colspan="3">Filler</td><td colspan="4">Mortar</td></tr>
<tr><td colspan="3">Buffer</td><td colspan="4">None</td></tr>
</table>

Source: NEA, 2019.

SOLID-MEDIUM-400-B

SOLID-MEDIUM-400-B is a waste package family that results from the treatment and conditioning of various solid wastes that had slowly accumulated in the Waste Department of the SCK·CEN[12] since the early sixties to the late eighties.

The waste is placed into 80-litre drums that are compacted into discs. These discs (four on average) are stacked into a 100-litre drum on a dry cement layer for moisture absorption. The 100-litre drum is then filled with sand, vibrated, shut and centrally immobilised in a 400-litre standard drum with cement grout. This latter is a LL-LILW according to the

compactable wastes in 220 litre drums on their premises. If this is not the case, the super-compactable LLW is separated from waste suitable for incineration and non-compactable waste and collected in 220 litre drums in the CILVA sorting unit.

12. This waste was of a variety of types and, by the end of the 1980s, their net volume amounted to about 200 cubic-metres. The final treatment and conditioning began in 2005. After reopening of the temporary storage container, the waste is checked for physical, chemical and radiological nature and dose rate. If the waste is within predefined limits, it is treated and conditioned immediately. Otherwise, it is transferred to the PAMELA facility.

Belgian classification, so it will be disposed of as detailed in Section 4.1.1., each "monolith" will accommodate eight 400-litre standard drums.

The concept above can be described using the data model given within Figure 3.2 as shown in Table 4.10 below.

Table 4.10: RepMet CDM applied to Belgian SOLID-MEDIUM-400-B

<table>
<tr><th colspan="4">Entity</th><th colspan="4">Description</th></tr>
<tr><td rowspan="11">Disposal Module</td><td rowspan="8">Waste Package (x8)</td><td rowspan="6">Wasteform</td><td rowspan="5">Waste</td><td rowspan="5">WP unfit for final disposal</td><td rowspan="3">Wasteform</td><td>Waste (x4)</td><td>Compacted 80-litre drums[13]</td></tr>
<tr><td>Stabiliser (1)</td><td>Cement layer</td></tr>
<tr><td>Stabiliser (2)</td><td>Sand</td></tr>
<tr><td colspan="2">WF Container</td><td>100 litre drum</td></tr>
<tr><td colspan="2">Overpack</td><td>None</td></tr>
<tr><td>Stabiliser</td><td colspan="4">Cement grout</td></tr>
<tr><td colspan="2">WF Container</td><td colspan="4">400-litre standard drum</td></tr>
<tr><td colspan="2">Overpack</td><td colspan="4">None</td></tr>
<tr><td colspan="3">WP Container</td><td colspan="4">Concrete caisson for geological disposal</td></tr>
<tr><td colspan="3">Filler</td><td colspan="4">Mortar</td></tr>
<tr><td colspan="3">Buffer</td><td colspan="4">None</td></tr>
</table>

Source: NEA, 2019.

LOW-LOT233-220

LOW-LOT233-220 is a waste package family that results from the heterogeneous embedding in bitumen of low-level alpha-bearing solid or liquid wastes produced at the EUROCHEMIC plant, the SCK-CEN, BELGONUCLEAIRE and some other third parties[14].

The treatment and conditioning operations were:

- For the solid waste: size reduction, compaction (where applicable) and placing in a 100-litre drum;
- For the liquid waste: neutralisation and mixing with Organic Portland Cement (OPC) in a 100-litre drum.

In both cases, 100-litre drum were then placed in 220-litre drum. After compaction (if applicable), bitumen would be poured into the 220-litre drum to fill the voids and immobilise the wastes. The final bituminised 220-litre drum is a LL-LILW according to

13. It would be possible to further develop the table nesting by considering the "compacted 80-litre drums" not directly as "waste", but as "waste package unfit for final disposal".

14. The wastes were treated and conditioned at the Waste Department of the SCK-CEN in the so-called "alfakamer".

the Belgian classification, thus it will be disposed of as reported above: each "monolith" will accommodate twelve 220-litre drums.

The concept above can be described using the data model given within Figure 3.2 as shown in Table 4.11 below.

Table 4.11: RepMet CDM applied to Belgian LOW-LOT233-220

<table>
<tr><th colspan="4">Entity</th><th colspan="4">Description</th></tr>
<tr><td rowspan="11">Disposal Module</td><td rowspan="8">Waste Package (x12)</td><td rowspan="6">Wasteform</td><td rowspan="5">Waste</td><td rowspan="5">WP unfit for final disposal (supercompacted)</td><td rowspan="3">Wasteform</td><td>Waste (1)</td><td>Solid waste</td></tr>
<tr><td>Waste (2)</td><td>Liquid waste</td></tr>
<tr><td>Stabiliser (2)</td><td>OPC</td></tr>
<tr><td colspan="2">WF Container</td><td>100 litre drum</td></tr>
<tr><td colspan="2">Overpack</td><td>None</td></tr>
<tr><td>Stabiliser</td><td colspan="4">Bitumen</td></tr>
<tr><td colspan="2">WF Container</td><td colspan="4">220 litre drum</td></tr>
<tr><td colspan="2">Overpack</td><td colspan="4">None</td></tr>
<tr><td colspan="3">WP Container</td><td colspan="4">Concrete caisson for geological disposal</td></tr>
<tr><td colspan="3">Filler</td><td colspan="4">Mortar</td></tr>
<tr><td colspan="3">Buffer</td><td colspan="4">None</td></tr>
</table>

Source: NEA, 2019.

RECOND-SCK-LOW-400

RECOND-SCK-LOW-400 is a waste package family originates from the reconditioning of LOW-LOT233-220 family (see Table 4.11), due to the premature container corrosion or the bitumen swelling for some waste packages.

The reconditioning consisted of the repackaging and immobilisation operations. Each damaged 220-litre drum was placed centrally into a 400-litre drum, and the annular space between them filled with cement grout. The final package is a LL-LILW according to the Belgian classification, thus it will be disposed of as reported above: each "monolith" will accommodate eight 400-litre drums.

The concept above can be described using the data model given within Figure 3.2 as shown in Table 4.12 below.

It is clear that, in this case, the LOW-LOT233-220 waste package equals the "WP unfit for final disposal" of RECOND-SCK-LOW-400. For this reason, in Table 4.12, the LOW-LOT233-220 waste package may be nested as waste for the RECOND-SCK-LOW-400 waste package.

Table 4.12: RepMet CDM applied to Belgian RECOND-SCK-LOW-400

<table>
<tr><th colspan="10">Entity</th><th>Description</th></tr>
<tr><td rowspan="13">Disposal Module</td><td rowspan="11">Waste Package (x8)</td><td rowspan="9">Wasteform</td><td rowspan="8">Waste</td><td rowspan="8">WP unfit for final disposal</td><td rowspan="6">Wasteform</td><td rowspan="5">Waste</td><td rowspan="5">WP unfit for final disposal</td><td rowspan="3">WF</td><td>Waste (1)</td><td>Solid waste</td></tr>
<tr><td>Waste (2)</td><td>Liquid waste</td></tr>
<tr><td>Stabiliser</td><td>OPC</td></tr>
<tr><td colspan="2">WF Container</td><td>100-litre drum</td></tr>
<tr><td colspan="2">Overpack</td><td>None</td></tr>
<tr><td colspan="4">Stabiliser</td><td>Bitumen</td></tr>
<tr><td colspan="5">WF Container</td><td>220-litre drum</td></tr>
<tr><td colspan="5">Overpack</td><td>None</td></tr>
<tr><td colspan="7">Stabiliser</td><td>Cement</td></tr>
<tr><td colspan="8">WF Container</td><td>400-litre drum</td></tr>
<tr><td colspan="8">Overpack</td><td>None</td></tr>
<tr><td colspan="9">WP Caisson</td><td>Concrete caisson for geological disposal</td></tr>
<tr><td colspan="9">Filler</td><td>Mortar</td></tr>
</table>

Source: NEA, 2019.

CONCT-KCD-LOW-400

CONCT-KCD-LOW-400 is a waste package family originates from the treatment and the conditioning of the aqueous effluent that the reactors of the Tihange NPP routinely generate[15].

The effluents are fed to an evaporator and then concentrated in order to minimise their bulky volume. The resulting concentrates are pH-adjusted, mixed with cementitious material and cast into 400-litre standard drum where the grout sets to form a homogeneous waste form[16]. The final package is a SL-LILW according to the Belgian classification, thus it will be disposed of as reported above: each "monolith" will accommodate four 400-litre standard drums.

The concept above can be described using the data model given within Figure 3.2 as shown in Table 4.13 below.

15. The effluent is produced by auxiliary circuits of the primary loop or various maintenance activities.

16. The waste treatment facility at the Tihange NPP only produces homogeneous cemented concentrates, without concomitant immobilization of other solid wastes.

Table 4.13: RepMet CDM applied to Belgian CONCT-KCD-LOW-400

Entity				Description
Disposal Module	Waste Package (x4)	WF	Waste	Evaporator concentrates
			Stabiliser	Cement
		WF Container		400-litre standard drum
		Overpack		None
	Disposal Container			Concrete caisson for surface disposal
	Filler			Mortar
	Buffer			None

Source: NEA, 2019.

MIXED-KCD-LOW-400

MIXED-KCD-LOW-400 is a waste package family originates from the treatment and the conditioning of various solid wastes and the aqueous effluents that the reactors of the Doel NPP routinely generate.

Table 4.14: RepMet CDM applied to Belgian MIXED-KCD-LOW-400

Entity				Description
Disposal Module	Waste Package (x4)	WF	Waste (1)	Solid waste
			Waste (2)	Evaporator concentrates
			Stabiliser	Cement
		WF Container		400 litre standard drum
		Overpack		None
	Disposal Container			Concrete caisson for surface disposal
	Filler			Mortar
	Buffer			None

Source: NEA, 2019.

For certain dose rate value[17], the solid waste is placed in 400-litre standard drums and then immobilised in a cement matrix. The evaporator concentrates, coming from the treatment of the aqueous effluents, are mixed in the same matrix allowing for simultaneous conditioning of solid and liquid wastes[18]. The final package is a SL-LILW according to the

17. The dose rate threshold value is 2 mSv/h. It is estimated when the solid wastes are initially collected in 220-litre standard drum for handling and transport reason.

18. That explains the name “MIXED” of the family.

Belgian classification, thus it will be disposed of as reported above: each "monolith" will accommodate four 400-litre standard drums.

The concept above can be described using the data model given within Figure 3.2 as shown in Table 4.14 above.

VITRO-60

VITRO-60 is a waste package family originates from the conditioning in the PAMELA plant of the LEWC[19] high-level liquid waste produced at the EUROCHEMIC spent fuel reprocessing plant.

Following the VITROMET process, the LEWC solution was directly calcinated by feeding into a molten borosilicate glass bath, with subsequent incorporation of the oxides into the vitreous medium. The molten glass containing fission product and transuranic oxides was cast as beads, which were poured into 60-litre stainless steel canisters with an inner basket. The canisters were then vibrated and filled with molten lead.

The concept above can be described using the data model given within Figure 3.2 as shown in Table 4.15 below.

Table 4.15: RepMet CDM applied to Belgian VITRO-60

<table>
<tr><th colspan="4">Entity</th><th>Description</th></tr>
<tr><td rowspan="8">Disposal Module</td><td rowspan="5">Waste Package (x10)</td><td rowspan="3">WF</td><td>Waste (1)</td><td>Liquid waste from SNF reprocessing</td></tr>
<tr><td>Stabiliser (1)</td><td>Glass (in bead)</td></tr>
<tr><td>Stabiliser (2)</td><td>Lead</td></tr>
<tr><td colspan="2">WF Container</td><td>60-litre PAMELA VITROMET canister</td></tr>
<tr><td colspan="2">Overpack</td><td>None</td></tr>
<tr><td colspan="3">Disposal Container</td><td>Concrete caisson for geological disposal</td></tr>
<tr><td colspan="3">Filler</td><td>Mortar</td></tr>
<tr><td colspan="3">Buffer</td><td>None</td></tr>
</table>

Source: NEA, 2019.

4.1.2. Hungarian packaging examples

There are two types of disposal units in Hungary for LILW originated in NPPs:

- Only one type of disposal unit is currently in operation and is based on a reinforced concrete container.
- The "compact waste package" is still in the licensing phase. For this latter type production designs have been created and the disposal facility has received a

19. LEWC (Low-Enriched Waste Concentrates) is a high-level waste solution containing significant amounts of process chemicals, especially sodium, in addition to the minor actinides and the fission products.

building licence modification (allowing the facility to receive this kind of package) however an operating licence has not yet been issued.

Reinforced container disposal unit

This kind of disposal unit is intended to be used for the final disposal of solid compacted waste in 200-litre drums. The reinforced container is designed to accommodate nine 200-litre drums. Waste arrives from the NPP in drums and the drums are then stored in the facility until they are cemented into the reinforced concrete container (Figure 4.6) by PURAM. The disposal unit is then transferred to the underground part of the facility where these containers are disposed of in a predetermined way.

The reinforced concrete containers are 2.25m x 2.25m x 1.38m in size and their weight is about 14 tonnes when fully loaded.

The concept above can be described using the data model given within Figure 3.2 as shown in Table 4 16 below.

Figure 4.6: RepMet CDM applied to Hungarian Reinforced container disposal unit

Source: PURAM, 2019.

Table 4.16: RepMet CDM applied to Hungarian Reinforced container disposal unit

Entity				Description
Disposal Module	Waste Package (x9)	WF	Waste	Compacted solid waste
			Stabiliser	None
		WF Container		200-litre drum
		Overpack		None
	Disposal Container			Reinforced concrete container
	Filler			Inactive mortar
	Buffer			None

Source: NEA, 2019.

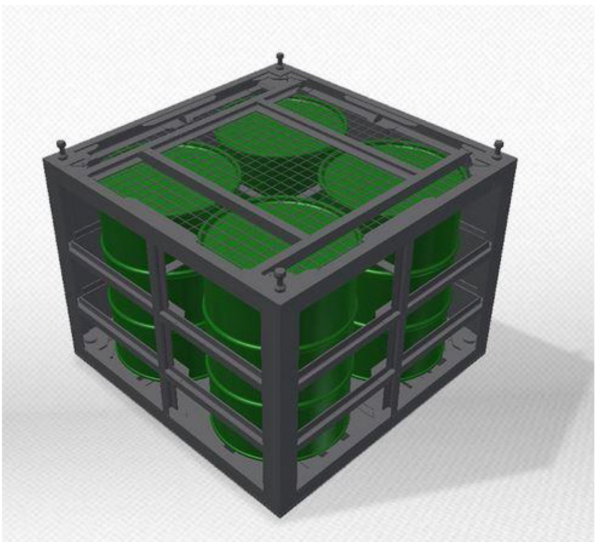
Compact waste package

The compact waste package will be produced in the NPP. The design is based on the concept of co-disposing solid and solidified liquid waste. Four 200-litre drums containing solidified waste are inserted into a 3 mm thick steel walled holding frame that provides support to the disposal unit. The void is then filled with mortar mixed in in a separate mixer. If the 200-litre drums contain non-compactable solid waste, active mortar is poured into the opened up drums.

To finish, a steel lid is screwed onto the top of the container. This complete package is then to be shipped to the disposal facility from the NPP.

This concept can be described using the data model given within Figure 3.2 as shown in Table 4.17 below.

Figure 4.7: Structural view of the compact waste package



Source: PURAM, 2019.

Table 4.17: RepMet CDM applied to Hungarian Compact waste package

<table>
<tr><th colspan="4">Entity</th><th>Description</th></tr>
<tr><td rowspan="8">Disposal Module</td><td rowspan="5">Waste Package (x4)</td><td rowspan="3">WF</td><td>Waste (1)</td><td>Compacted or non-compacted solid waste</td></tr>
<tr><td>Waste (2)</td><td>Liquid waste</td></tr>
<tr><td>Stabiliser</td><td>Solidifier for liquid waste</td></tr>
<tr><td colspan="2">WF Container</td><td>200-litre drum</td></tr>
<tr><td colspan="2">Overpack</td><td>None</td></tr>
<tr><td colspan="3">Disposal Container</td><td>3 mm thick steel walled holding frame</td></tr>
<tr><td colspan="3">Filler</td><td>None</td></tr>
<tr><td colspan="3">Buffer</td><td>None</td></tr>
</table>

Source: NEA, 2019.

4.1.3. UK packaging examples

UK packaged ILW: Cemented Disposal Unit

Within the United Kingdom one disposal concept being considered for ILW is a 500-litre metal walled drum in which waste is added along with cement. The cement is mixed with the waste using an in-drum mixer and once it sets a capping grout is applied before the drum is sealed. Four such drums are placed in a holding frame (stillage) for emplacement within a disposal facility; this is referred to as a disposal unit (Figure 4.8).

Figure 4.8: In-package grouted wasteform in a 500-litre drum (left) and the disposal unit (right)

Note: the concept can be described using the data model given within Figure 3.2 as shown in Table 4.18.
Source: NDA/RWM, 2019.

Table 4.18: RepMet CDM applied to UK Cemented Disposal Unit

<table>
<tr><th colspan="4">Entity</th><th>Description</th></tr>
<tr><td rowspan="8">Disposal Module</td><td rowspan="5">Waste Package (x4)</td><td rowspan="3">WF</td><td>Waste</td><td>Metals[20] etc. for disposal</td></tr>
<tr><td>Stabiliser (1)</td><td>Cement</td></tr>
<tr><td>Stabiliser (2)</td><td>Capping grout</td></tr>
<tr><td colspan="2">WF Container</td><td>500-litre metal drum and in-drum mixer</td></tr>
<tr><td colspan="2">Overpack</td><td>None</td></tr>
<tr><td colspan="3">Disposal Container</td><td>Holding frame</td></tr>
<tr><td colspan="3">Filler</td><td>None</td></tr>
<tr><td colspan="3">Buffer</td><td>None</td></tr>
</table>

Source: NEA, 2019.

4.1.4. US packaging examples

US transuranic waste

In the United States, a current disposal method for LILW is using a steel, 55 gallon (~208-litre) drum as a waste container as shown in Figure 4.9. In Figure 4.9 (right side), from left to the right: the first drum contains glassware; the second drum is filled with sludge from the processing line where separation of plutonium from other materials takes place; the third drum contains assorted hardware; and the fourth contains clothing and organic waste.

Figure 4.9: Typical 55 gallon, steel drum (left) and typical radioactive waste cross section of drums containing typical transuranic waste (right)

Source: Sandia National Laboratories, 2019.

20. The metals are MAGNOX swarf, alias the outside of MAGNOX fuel elements stripped off during the reprocessing at the Sellafield nuclear site.

The waste container is then placed in the repository, either near-surface or deep repository dependent upon the classification of the waste. A typical near-surface facility is shown in Figure 4.10 while the WIPP (Waste Isolation Pilot Plant) deep repository is shown in Figure 4.11. Once the drums of radioactive waste are stored in the permanent disposal area of the WIPP underground facility, salt creep over time will cover and entomb the drums thus preventing release of radioactivity.

This can be described using the data model given in Figure 3.2 and as shown in Table 4.19.

Table 4.19: RepMet CDM applied to US Transuranic Waste

<table>
<tr><th colspan="4">Entity</th><th>Description</th></tr>
<tr><td rowspan="7">Disposal Module</td><td rowspan="4">Waste Package</td><td rowspan="2">WF</td><td>Waste</td><td>Contaminated glassware, personal protective equipment, processing sludge, etc.</td></tr>
<tr><td>Stabiliser</td><td>None</td></tr>
<tr><td colspan="2">WF Container</td><td>55-gallon (~208-litre) metal drum</td></tr>
<tr><td colspan="2">Overpack</td><td>None</td></tr>
<tr><td colspan="3">Disposal Container</td><td>None</td></tr>
<tr><td colspan="3">Filler</td><td>None</td></tr>
<tr><td colspan="3">Buffer</td><td>None</td></tr>
</table>

Source: NEA, 2019.

Figure 4.10: Typical low-level radioactive waste emplacement in a trench at the Nevada Test Site (now called the Nevada National Nuclear Site)

Source: Sandia National Laboratories, 2019.

Figure 4.11: Typical intermediate-level radioactive waste emplacement

Source: Sandia National Laboratories, 2019.

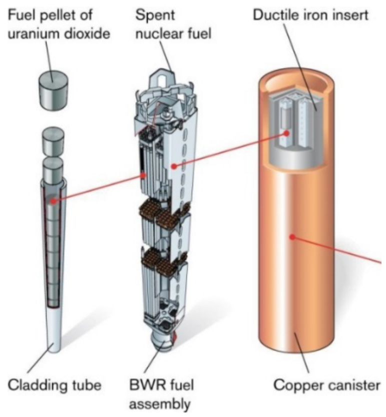
4.1.5. Swedish packaging examples

Swedish packaged SNF: KBS-3 disposal system

The Swedish policy for the management of SNF is direct disposal in bedrock geological formation at 400-700 m depth. The final repository, called KBS-3, is based on the multi barrier principle.

The parts of a KBS-3 repository acting as barriers are: the spent fuel material with low dissolution rate in the repository environment; the canister with its tight corrosion resistant copper shell and load-bearing insert; the buffer that prevents flow of water and protects the canister; and the bedrock that isolates the repository from the surface environment and provides suitable and stable conditions for the engineered barriers.

Figure 4.12: The SNF and canister for disposal in a KBS-3 repository

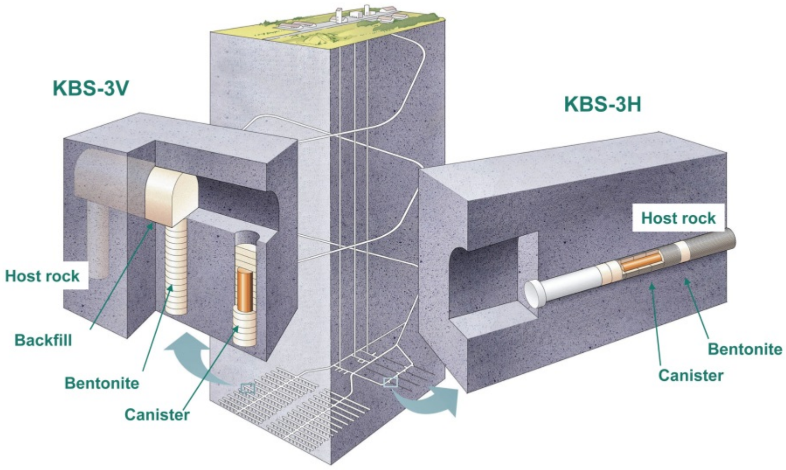


Source: SKB, 2019.

SKB, jointly with the Finnish Posiva, investigated two versions of the KBS-3 disposal system shown in Figure 4.13:

- KBS-3V for vertical deposition in the rock of the encapsulated SNF;
- KBS-3H for horizontal deposition in the rock of the encapsulated SNF:

Figure 4.13: KBS-3V and KBS-3H disposal system for encapsulated SNF



Source: SKB, 2019.

The following sections show how to apply the CDM in Figure 3.2 for both versions of the KBS-3 disposal system.

KBS-3V disposal system

In the KBS-3V disposal system, canisters are emplaced in vertical deposition hole. Each canister is surrounded by bentonite buffer, installed in the deposition hole prior to the disposal of the canister.

This can be described using the data model given in Figure 3.2 and as shown in Table 4.20. In this case, the buffer is not included since it is not installed in the repository together with the canister. Within the RepMet data models, engineered barriers that are not installed together with the waste packages are referred to as repository engineered barriers.

Table 4.20: RepMet CDM applied to Swedish KBS-3V Disposal System

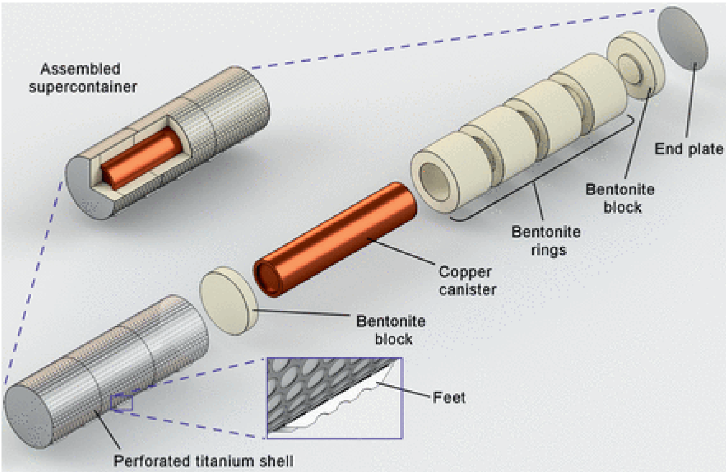
Entity				Description
Disposal Module	Waste Package	WF	SNF (x4 or x12)	PWR-type or BWR-type SNF assembly
			Stabiliser	None
		WF Container		Copper canister with cast iron insert
		Overpack		None
	Disposal Container			None
	Filler			None
	Buffer			None

Source: NEA, 2019.

KBS-3H disposal system

In the KBS-3H disposal system, multiple canisters containing spent fuel are emplaced in approximately 300 m long deposition drifts, slightly inclined towards the transport tunnel. Each canister together with its surrounding bentonite buffer is placed in a perforated steel shell. This module, called a supercontainer, is used to dispose the canister and install the buffer at the same time (see Figure 4.14).

Figure 4.14: KBS-3H disposal system for encapsulated SNF



Source: SKB, 2019.

This can be described using the data model given within Figure 3.2 as shown in Table 4.21. In this case, the buffer is included since it is placed in the disposal module. Within the RepMet data models, engineered barriers placed in disposal modules are referred to as waste engineered barriers.

Table 4.21: RepMet CDM applied to Swedish KBS-3H Disposal System

Entity				Description
Disposal Module	Waste Package	WF	SNF (x4 or x12)	PWR-type or BWR-type SNF assembly
			Stabiliser	None
		WF Container		Copper canister with cast iron insert
		Overpack		None
	Disposal Container			Perforated titanium shell
	Filler			None
	Buffer			Bentonite rings and blocks

Source: NEA, 2019.

4.2. Example application of the O&M CDM

The example application of the Waste Package Library CDM for the Belgian deep disposal "Monolith" (see section 4.1.1) uses the AREVA CSD-C waste package. As reported in Table 4.2, this waste package is a stainless steel container (wasteform container) containing the structural waste, (hulls and end-pieces) from the LWR SNF reprocessing operations (waste).

This section illustrates how data and metadata in a record about the waste in the AREVA CSD-C waste package would be mapped to the entities of the CDM in Figure 3.8 and its related attributes.

The following is the set of data that RepMet assumed to be known about such waste, each one was obtained through different ways[21].

- Mass of the waste through weighing: 600 kg;
- Presence of combustible materials and reactive agents through chemical testing: none for both items;
- Radioactivity of the gamma emitters ^{60}Co, ^{125}Sb, ^{134}Cs, ^{137}Cs, ^{154}Eu through gamma spectroscopy: 9.3 TBq, 1.1 TBq, 10.0 GBq, 9.5 TBq and 10.0 GBq respectively;
- Radioactivity of fissile radionuclide such as ^{235}U, ^{238}U, ^{239}Pu, ^{241}Pu through active neutron interrogation, ^{235}U/^{238}U and ^{241}Pu/^{239}Pu correlations: 1.0 TBq, 1.0 TBq, 38.0 GBq and 5.6 TBq respectively;
- Radioactivity of ^{244}Cm through passive neutron counting: 44.0 GBq; and
- Radioactivity of hard to measure radionuclides (HTMR) ^{55}Fe, ^{63}Ni, ^{90}Sr, ^{238}Pu, ^{240}Pu through empirical correlations: 6.5 TBq, 20.0 TBq, 8.9 TBq, 260.0 GBq and 590.0 GBq respectively.

According to the O&M standard, these data are the results of the estimation of the values of some property about a "feature of interest". This is the waste in the AREVA CSD-C waste package, obtained during an observation act and following specific procedures. Table 4.22 shows the cross-reference between the reported sets of data and the O&M standard interpretation.

21. These data are not officially provided by AREVA, and have been developed for example purposes only. RepMet developed these data based on scientific papers available online and reported in the references: Chotin et al., 1998; Gain, 2001; Tietze-Jaensch et al., 2012; Tietze-Jaensch et al., 2013; and Toubon et al. 2001.

Table 4.22: Interpretation of data sets assumed for the AREVA CSD-C waste package according to the O&M standard

Properties	Observations	Results
Mass of the waste	Weighing	600 kg
Combustible materials; Reactive agents	Chemical test	None
Radioactivity of ^{60}Co, ^{125}Sb, ^{134}Cs, ^{137}Cs, ^{154}Eu	Gamma spectroscopy	9.3 TBq, 1.1 TBq, 10.0 GBq, 9.5 TBq and 10.0 GBq
Radioactivity of fissile radionuclide such as ^{235}U, ^{238}U, ^{239}Pu, ^{241}Pu	Active neutron interrogation + $^{235}U/^{238}U$ and $^{241}Pu/^{239}Pu$ correlations	1.0 TBq, 1.0 TBq, 38.0 GBq and 5.6 TBq
Radioactivity of ^{244}Cm	Passive neutron counting	44.0 GBq
Radioactivity of hard to measure radionuclides (HTMR) ^{55}Fe, ^{63}Ni, ^{90}Sr, ^{238}Pu, ^{240}Pu	Empirical correlations	6.5 TBq, 20.0 TBq, 8.9 TBq, 260.0 GBq, 590.0 GBq

Source: NEA, 2019.

The following tables show how the entities and their attributes of the Waste Package Library and O&M CDMs in Figure 3.8 can be used to collect all these data in a structured fashion.

Table 4.23 illustrates the example instance of the waste entity including the related attributes for the AREVA CSD-C waste package.

Table 4.23: Instance of waste entity and attributes for AREVA CSD-C

Entity	Attribute		Value
Waste	Record	Waste ID	ABCD1234
		National classification	MA-VL (Moyenne Activité à Vie Longue), RSC_WST-1
		International classification	ILW-LL (Intermediate-Level Waste - Long Lived), RSC_WST-2
		Waste owner	EDF, RSC_WST-3
		Waste producer	AREVA, RSC_WST-4
		Origin of the raw waste	SNF reprocessing, RSC_WST-5
		Description of the raw waste	Hulls and end-pieces in Zircalloy-4 from the reprocessing of PWR-type SNF assemblies. The waste includes the technological wastes from the reprocessing activities.
	Observation	wasteObservation[1]	OBS_WST_0001, Weighing
		wasteObservation[2]	OBS_WST_0002, Chemical test
		wasteObservation[3]	OBS_WST_0003, Gamma spectroscopy
		wasteObservation[4]	OBS_WST_0004, Active neutron interrogation (Prompt and delayed neutron counting)
		wasteObservation[5]	OBS_WST_0005, Passive neutron counting
		wasteObservation[6]	OBS_WST_0006, Empirical correlation

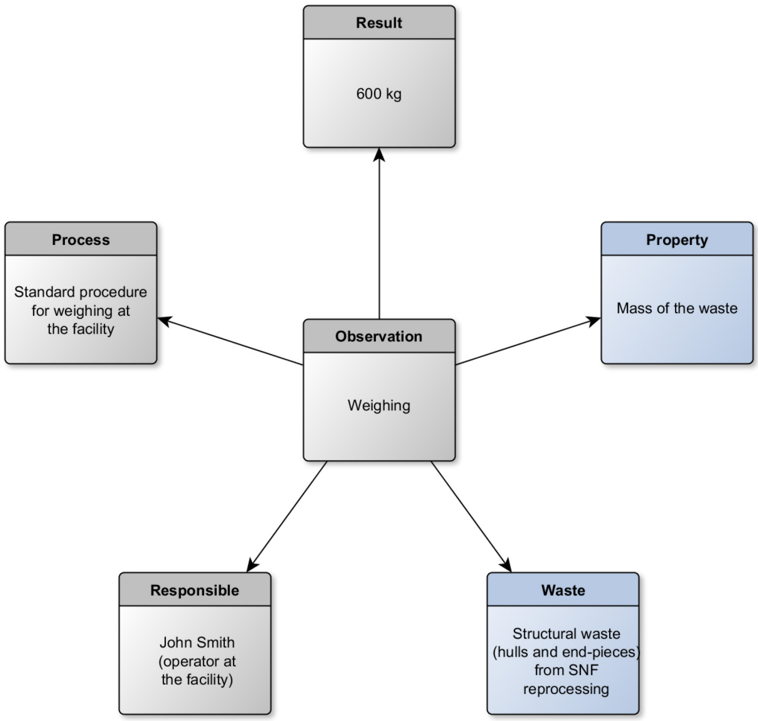
Source: NEA, 2019.

"Weighing" is an observation act following a given procedure and resulting in the estimation of the value of a physical property, such as the mass of the waste in the AREVA CSD-C. Figure 4.15 helps in the visualisation of this concept. The same general concept can be applied to all the other types of observation involved. For example, "gamma spectroscopy" is an observation act following a given procedure and resulting in the estimation of the gamma activity of gamma emitters such as ^{60}Co, ^{125}Sb, ^{134}Cs, ^{137}Cs and ^{154}Eu.

Table 4.24 illustrates the instance of the observation entity including the related attributes for "weighing". Table 4.23 and Table 4.24 are clearly linked to the weighing observation through its identifier (i.e. OBS_WST_0001). The colour coding for the two tables helps in the visualisation of the connection between them.

Table 4.25 illustrates the instance of the property entity for "mass of raw waste". The observed properties are selected from the list of attribute data that RepMet created for each Waste Package Library CDM and arranged in the form of controlled dictionary as explained in Chapter 5. Note that the name of the property "mass of raw waste" coincides with one of the attribute of the Waste entity. For this item, RepMet identified several additional data such as definition, definition source and purpose for collecting.

Figure 4.15: Conceptual picture of a weighing observation



Source: NEA, 2019.

Table 4.24: Instance of observation entity and attributes for "weighing"

Entity	Attribute	Value
Observation	identifier	OBS_WST_0001
	name	Weighing
	responsible	operator: John Smith
	observedProperty	WASTE/Physical_Properties/Mass_of_raw_waste
	phenomenonTime	2000-01-01T12:00:00:00.000
	resultTime	2000-02-01T12:00:00:00.000
	procedure	PRC_WST-01, CSD-C Weighing
	result	Mass of raw waste = 600 kg

Source: NEA, 2019.

Table 4.25: Instance of property entity and attributes for "mass of waste"

Entity	Attribute	Value
Property	Name	Mass of raw waste (linked to a proper controlled dictionary (see Chapter 5. for an example from RepMet)

Source: NEA, 2019.

Table 4.26 illustrates the instance of the process entity including the related attributes for "CSD-C weighing" that might be used as the standard procedure for weighing the waste at the treatment and conditioning facility. The piece of information included in this entity is useful to keep track of the process that resulted in the estimation of the value for the property.

Table 4.26: Instance of process entity and attributes for "CSD-C Weighing"

Entity	Attribute	Value
Process	identifier	PRC_WST-01
	name	CSD-C Weighing
	type	X (poiting to a proper controlled dictionary)
	documentation	http://repmet/processes/howToMeasureWeightOfWaste[22]
	responsible	custodian: Mario Rossi

Source: NEA, 2019.

22. The URLs provided in Table 4.26 through to Table 4.32 are provided as examples only and do not currently link to any live resources. Within a RWMO these URLs could link to intranet based documentation resources.

Table 4.30 illustrate analogous instances related to the “chemical test” observation. The two chemical properties of the waste, “combustible materials” and “reactive agents” are grouped into one record. The assumption is that only the results are important, and that details of the measuring processes are either not available or not of the interest to the user. In other cases, when circumstances of individual chemical tests are relevant the same example would be presented as separate observations providing details for each individual property.

Table 4.27: Instance for observation entity and attributes for “chemical test”

Entity	Attribute	Value
Observation	identifier	OBS_WST_0002
	name	CSD-C Chemical test
	responsible	operator : John Smith
	observedProperty[1]	WASTE/Chemical_Properties/Combustible_agents
	observedProperty[2]	WASTE/Chemical_Properties/Reactive_agents
	phenomenonTime	2000-01-01T12:00:00:00.000
	resultTime	2000-02-01T12:00:00:00.000
	procedure	PRC_WST-02, CSD-C Chemical test
	Result	Combustible agents = none
		Reactive agents = none

Source: NEA, 2019.

Table 4.28: Instance of property entity and attributes for “combustible materials”

Entity	Attribute	Value
Property	Name	Combustible materials (linked to a proper controlled dictionary)

Source: NEA, 2019.

Table 4.29: Instance of property entity and attributes for “reactive agents”

Entity	Attribute	Value
Property	Name	Reactive agents (linked to a proper controlled dictionary)

Source: NEA, 2019.

Table 4.30: Instance of process entity and attributes for "CSD-C Chemical test"

Entity	Attribute	Value
Process	Identifier	PRC_WST-02
	Name	CSD-C Chemical test
	Type	X (pointing to a proper controlled dictionary)
	Documentation	http://repmet/processes/howToMeasureWeightOfWaste
	responsibleParty	custodian: Mario Rossi

Source: NEA, 2019.

Table 4.31: Instance of observation entity and attributes for "gamma spectroscopy"

Entity	Attribute	Value	
Observation	identifier	OBS_WST_0003	
	name	Gamma spectroscopy	
	responsible	operator: John Smith	
	observedProperty[1]	WASTE/Radiological_properties/60Co/Activity	
	observedProperty[2]	WASTE/Radiological_properties/125Sb/Activity	
	observedProperty[3]	WASTE/Radiological_properties/134Cs/Activity	
	observedProperty[4]	WASTE/Radiological_properties/137Cs/Activity	
	observedProperty[5]	WASTE/Radiological_properties/154Eu/Activity	
	phenomenonTime	2000-01-01T12:00:00:00.000	
	resultTime	2000-02-01T12:00:00:00.000	
	Procedure	PRC_WST-03, Gamma spectroscopy	
	Result	^{60}Co activity = 9.3 TBq	^{134}Cs activity =10.0 GBq
		^{125}Sb activity = 1.1 TBq	^{137}Cs activity = 9.5 TBq
		^{154}Eu activity = 10 GBq	

Source: NEA, 2019.

Table 4.31 provides an application example of the observation entity for the "gamma spectroscopy" observation. No further details are provided.

Looking at Table 4.23, each value of the set of attributes belonging to the "record group" may be referenced and point to further resources available online, offline or as printed documents. The attributes "National classification", "International classification", "Waste owner", "Waste producer" and "Origin of the raw waste" may be identified and instanced with the resource entity of the MRMS. Table 4.32 shows the related example applications assuming that the external resources are pdf documents available at specific URLs.

Table 4.32: Data model applied to referenced waste data resources[23]

Entity	Attribute	Value
Resource	Identifier	RSC_WST-1
	Title	MA-VL (Moyenne Activité à Vie Longue)
	Format	PDF
	Location	http://repmet/resources/download?id=MA-VL.pdf

Entity	Attribute	Value
Resource	Identifier	RSC_WST-2
	Title	ILW-LL (Intermediate-Level Waste - Long Lived)
	Format	PDF
	Location	http://repmet/resources/download?id=ILW-LL.pdf

Entity	Attribute	Value
Resource	Identifier	RSC_WST-3
	Title	EDF
	Format	PDF
	Location	http://repmet/resources/download?id=EDF.pdf

Entity	Attribute	Value
Resource	Identifier	RSC_WST-4
	Title	AREVA
	Format	PDF
	Location	http://repmet/resources/download?id=AREVA.pdf

Entity	Attribute	Value
Resource	Identifier	RSC_WST-5
	Title	SNF reprocessing
	Format	PDF
	Location	http://repmet/resources/download?id=CSD-C_description.pdf

Source: NEA, 2019.

23. All webpages accessed in June 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 Wide Web Consortium (W3C) has developed.

The design of a CDM such as that presented in Chapter 3requires a special effort on the definition of the meaning of the entities such as radioactive waste and SNF in the Waste Package 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 Waste Package Library CDM (Figure 3.2) and the Spent Nuclear Fuel CDM (Figure 3.3). 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 Waste Package 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 Waste Package 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[24] 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;

-*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 Waste Package Library after a thorough investigation of available information sources:

- internal questionnaires about the data that the RWMOs and the research laboratories were already collecting for packaged LILW;
- 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.

RepMet questionnaires

At the very beginning of the initiative, the RepMet group produced two questionnaires to give an overview of the data about packaged LILW ready for final disposal that was already being collected.

The two questionnaires were organised around a number of high-level categories (e.g. *wasteform*, *container*, *overpack*), each of which listed potentially relevant properties for which data might be collected. Respondents were asked to identify whether they collected data about each property, and to explain the reasons for its collection (storage, transport, or final disposal), pointing to relevant documentation and adding further information as necessary. Moreover, they were asked to report any additional property items, not included in the original questionnaire list.

- NEA prepared the "1st Questionnaire" that was composed of 90 items in five high-level categories (*WP receipt*, *WP physical-chemical properties*, *container*, *wasteform* and *WP handling*). Eleven[25] organisations responded to the 1st Questionnaire: they added 206 properties to the initial 90.

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

25. RWMOs replying to the 1st Questionnaire: Andra (France), ENRESA (Spain), JAEA (Japan), Magnox Ltd (United Kingdom), Nagra (Switzerland), ONDRAF/NIRAS (Belgium), PURAM (Hungary), Sandia National Laboratories (United States), Sellafield Ltd (United Kingdom), SKB (Sweden), SURAO (Czech Republic).

The "2nd Questionnaire" was developed in order to organise the new properties coming from the 1st Questionnaire in a more structured and complete way (e.g. new arrangement of high-level categories, deletion of overlapping items, merging of redundant items). The revised questionnaire contained 157 property items in seven high-level categories (*waste*, *wasteform*, *encapsulant*, *container*, *overpack*, *waste package* and *waste package history*). Thirteen[26] organisations responded to the second questionnaire (two more than for the first questionnaire): they added only 30 items. New respondents added half of these new items; the other half were due to increased detail for generic items or the inclusion of additional topics such as radioactive spent sources.

The analysis of the second questionnaire gave confidence that the list of properties about packaged LILW was comprehensive. This final list of properties was used as an input for the development of the list of attributes for the entities of the Waste Package Library CDMs.

Public documents

In addition to the results of the RepMet Questionnaires, the group decided to adopt some extra relevant sources without confidentiality restrictions. The major sources were

- LLWR Ltd. – Waste Acceptance Criteria (WAC) Low-Level Waste Disposal (Version 4.0, March 2014) (LLWR Ltd, 2014);
- EU 1357/2014 of 18 December 2014 (European Union, 2014).

The first source is the WAC of the Low-Level Waste Repository (LLWR) facility, a near-surface repository for the disposal of very low-level waste (VLLW) and LLW at Drigg in the Cumbria region (United Kingdom). The operator, the LLWR Ltd. Company, accepts solid waste only and offers several services for the treatment and conditioning of waste for volume reduction (e.g. supercompaction, incineration, metal recycling). This document is part of the Waste Services Contract between the Low Level Radioactive Waste (LLRW) Ltd and its customers: the provided WAC includes physical, chemical, radiological, packaging and transport requirements that waste must comply with to be accepted at the facility for disposal. These multiple requirements were taken into account to enhance the list of entity attributes.

The second source is a European Union (EU) regulation that replaced Annex III of the EU Directive 2008/98 (European Union, 2008) concerning the management of conventional waste. The main content of this source that RepMet adopted for the attribute selection and definition was the classification system for the hazardous properties of waste. In fact, the source defines 15 classes of hazardous properties for waste that RepMet included in the list of attributes associated to the Waste entity of the Waste Package CDM (Figure 3.2).

Additional support from the RWMO involved in RepMet

The RWMOs involved in the RepMet initiative provided some additional documentation to extend and improve the list of attributes in the Waste Package Library. Among them, the Swedish SKB provided the list of data and metadata that they are currently collecting about

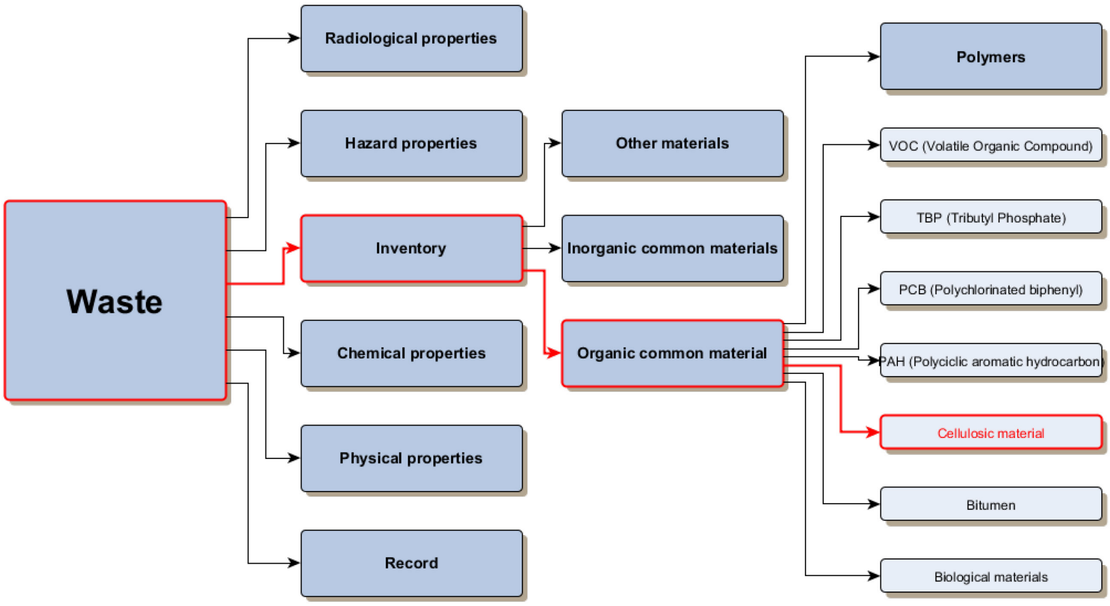
26. RWMOs replying to the 2nd Questionnaire: Andra (France), UK-EDF (United Kingdom), JAEA (Japan), Magnox Ltd (United Kingdom), former RSRL (United Kingdom), Nagra (Switzerland), NWMO (Canada), ONDRAF/NIRAS (Belgium), PURAM (Hungary), Sellafield Ltd (United Kingdom), Sandia National Laboratories (United States), SKB (Sweden), SURAO (Czech Republic).

SNF and the RepMet team used this list to define the entities and the related attributes of the Spent Nuclear Fuel CDM (section 3.3).

5.2.2. Step 2 – Mind-map

The outputs of Step 1 are the lists of attributes for each entity of the Waste Package 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 a small portion of the mind-map associated with the "Waste" entity.

Figure 5.1: Controlled dictionary for "Waste"– Partial mind-map visualisation



Source: NEA, 2019.

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 Waste Package Library, leaving aside the special national requirements, it is clear that the reason for considering an attribute is mainly related to the safety of transport, interim storage and disposal of the packaged waste and SNF. That means that a controlled dictionary designed in this way can support the development of safety cases (e.g. operational safety case or post-closure safety case for a repository).

As Figure 5.1 shows, “cellulosic material” is an attribute of the “waste” entity in the library. Taking the example further, Table 5.2 shows the values that the RepMet group identified for the features of the “cellulosic material” attribute.

Table 5.2: Features of the “cellulosic material” attribute

Features	Values
Definition	Material containing cellule, an organic natural polymer with the formula $(C_6H_{10}O_5)n$.
Definition source	-
Purpose	Cellulosic material can degrade by microbial action and alkaline hydrolysis to form acidic species and to increase the pH environment.
Comment	Examples of cellulosic material are cotton, natural textile fibres, paper, wood.

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 “cellulosic material” resource-attribute), predicates according to the SKOS vocabulary, and objects.

Table 5.3: "Cellulosic material" RDF triples[27]

"Cellulosic material" - 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/Waste/n0 ("Waste" resource)
	skos:broader	https://www.oecd-nea.org/rwm/igsc/repmet/Waste/n26 ("Organic common material" resource)
	skos:prefLabel	Cellulosic material @en
	skos:definition	Material containing cellule, an organic natural polymer with the formula $(C_6H_{10}O_5)n$
	dc:source	-
	skos:scopeNote	Cellulosic material can degrade by microbial action and alkaline hydrolysis to form acidic species and to increase the pH environment
	skos:comment	Examples of cellulosic material are: cotton, natural textile fibres, paper, wood

Source: NEA, 2019.

Examining Table 5.3 row by row, the "cellulosic material" attribute which is the SKOS concept "rpm:Waste/n53"[28] has the following features:

- It belongs to the SKOS concept scheme identified as "rpm:Waste/n0" (i.e. the "Waste" entity);
- It has a broader SKOS concept available identified as "rpm:Waste/n26" (i.e. the "Organic common material");
- It has as preferred label in English "Cellulosic material";
- It is defined as "Material containing cellule, an organic natural polymer with the formula $(C_6H_{10}O_5)_n$, and this definition has not an external source";
- It has to be taken into account by the RWMOs for the waste chemical inventory since the "cellulosic material can degrade by microbial action and alkaline hydrolysis to form acidic species and to increase the pH environment";
- There is a comment that "examples of cellulosic material are cotton, natural textile fibres, paper, wood".

The set of RDF triples describing each resource (i.e. each attribute of the Waste Package Library) are available online under the NEA web domain in both human (i.e. HTML) and machine-readable (i.e. XML serialisation) format.

27. 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.

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

Table 5.4 and Figure 5.2 illustrate the two mentioned formats for the "cellulosic material" 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: "Cellulosic material" RDF description – Human-readable format (HTML)

ID	http://www.oecd-nea.org/repmet/Waste/n53
RDF Type	http://www.w3.org/2004/02/skos/core#Concept[29]
Broader term	Organic common material
Name	Cellulosic material
Definition	Material containing cellule, an organic natural polymer with the formula (C6H10O5)n
Comment	Examples of cellulosic material are cotton, natural textile fibres, paper, wood
Definition source	-
Purpose	Cellulosic material can degrade by microbial action and alkaline hydrolysis to form acidic species and to increase the pH environment

Source: NEA, 2019.

Figure 5.2: "Cellulosic material" RDF description – Machine-readable format (XML serialisation)

"Cellulosic material" 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">Cellulosic material</skos:prefLabel>
    <skos:definition xml:lang="en">
      Material containing cellule, an organic natural polymer with the formula (C6H10O5)n.
    </skos:definition>
    <dc:source>-</dc:source>
```


29. Accessed June 2019.

```
      <rdfs:comment xml:lang="en">
        Examples of cellulosic material are: cotton, natural textile fibres, paper, wood.
      </rdfs:comment>
      <skos:scopeNote>
        Cellulosic material can degrade by microbial action and alkaline hydrolysis to form acidic species and to decrease
        the pH environment.
      </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 3.2 (Waste Package) and Figure 3.3 (SNF)

  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 Waste Package Library is a technical product of the IGSC RepMet initiative. It is composed of a report (this document) and an associated technical library dealing with data and related metadata about packaged waste and spent nuclear fuel (SNF) that, after proper treatment and conditioning processes, are ready for final disposal at the repository.

The Waste Package Library has two principal aims:

- To identify the "core information" about packaged waste and SNF ready for final disposal, built on the data that the Radioactive Waste Management Organisations (RWMOs) involved in RepMet are currently collecting;
- To provide application examples about how implementing the metadata-based techniques can support the long-term management of the "core information" about packaged waste and SNF ready for final disposal.

The library includes high-level and original conceptual data models (CDMs), descriptions of data entities, attributes, associated metadata and controlled dictionaries. The library also includes real-world application examples based on waste packages used by organisations involved in RepMet.

RWMOs can reuse and further extend the models and controlled dictionaries in the development of their own data and information systems.

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 the waste packaging, 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.

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 Waste Package 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. 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 Feature, Event and Process (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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