SECONDARY WASTE MANAGEMENT; DOMAIN INSIGHT 2.3.3

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OVERVIEW

With the objectives to optimize the management of radioactive waste throughout the predisposal phase, waste producers and repository operators have to consider the generation of secondary radioactive waste in every operation and all processes they apply, the classification of this waste and the route in which it is subsequently treated. By definition, secondary waste is a form or a type of waste that results as a by-product from waste processing and can be generated from different sources and be of a different nature. Once produced, secondary waste must be inventoried, characterized and treated, and its management is the same as for primary waste.

The current processes are described in the Domain Insight 2.3.3 Secondary Waste Management.

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KEYWORDS

Predisposal, processing, optimisation, volume reduction, treatment, pre-treatment,

KEY ACRONYMS

GBS – goals breakdown structure
IAEA – International Atomic Energy Agency
LILW – Low- and Intermediate-Level Waste
RLOW – Radioactive Liquid Organic Waste
RSOW – Radioactive Solid Organic Waste
WAC – Waste Acceptance Criteria

1 TYPICAL OVERALL GOALS AND ACTIVITIES IN THE DOMAIN OF SECONDARY WASTE MANAGEMENT

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

Domain Goal	
2.3.3 Manage secondary waste streams produced during initial processing, for applying a lifecycle approach (Secondary Waste Management).	
Domain Activities	
Phase 1: Planning and Programme Initiation	Anticipate the generation, the nature, and if possible, the quantity of secondary waste generated during the treatment of radioactive waste (DI 2.2.2 – Treatment and Processing) and decontamination processes. Comparison of the processing options to minimize the volume of secondary waste generated with the assurance that there is a mature solution for their management.
Phase 2: Program Implementation	Characterisation of the secondary waste to apply the most appropriate solution for their management (DIs 2.1.4 – Waste hierarchy, 2.2.1 – Characterisation).

Phases 3–4: Program Operation/Optimisation and Closure	Manage iterative reviews and updates of waste hierarchies and WAC.

2 INTERNATIONAL LEGISLATION

There is no international legislation exclusively related to the Secondary Waste Management. Once generated, this category of waste must follow the same protocol and rules than primary waste.

More detailed information related to the international legislation can be found in the DIs (e.g. 2.1.3 – Technology Selection, 2.2.1 – Characterization, 2.2.2 – Treatment and Processing). In general each country has its own nuclear waste management policy and its national regulations that influence the management of radioactive waste including the secondary waste.

3 GENERIC SAFETY ISSUES FOR SEONCDARY WASTE MANAGEMENT

This section describes the safety precautions associated with radioactive secondary waste management issues during each of the three phases noted in the table of Section 1. They are described with respect to a waste management program, addressing pre-disposal activities (prior to final geological disposal). It should be noted that the safety and regulations issues do not change during the three phases yet are reviewed iteratively through each phase and with progressively greater detail.

3.1 Planning and Program Initiation

In the early phases of pre-disposal program initiation, it is essential to consider the full 'life cycle' of the processes that may produce primary waste and to anticipate the generation, the nature and, if possible, the quantity of secondary waste from these processes. The nature of the secondary waste is likely to differ from that of the primary waste streams treated (e.g., treatment of RLOW may generates RSOW) and must be identified beforehand. The types of secondary waste expected to be generated during primary treatment are shown in the table below (see DI 2.2.2 – Treatment and Processing)

Secondary waste generated relating to the treatment technologies for **liquid organic waste**:

Liquid organic waste treatment and expected secondary waste	
Distillation	Evaporator, bottom concentrate

Liquid-liquid extraction	Aqueous waste
Absorption	Solid waste absorbents
Incineration (including conventional incinerators – stared air, excess air, rotary kilns and high temperature incinerators with plasma torches)	Ash residue, off gases filters, scrub solutions
Emulsification	Alkaline aqueous waste, separated diluent
Alkaline hydrolysis	Alkaline aqueous waste, separated diluent

- Distillation: evaporator, bottom concentrate
- Liquid-liquid extraction: aqueous waste
- Absorption: solid waste absorbents
- Incineration (including conventional incinerators – stared air, excess air, rotary kilns and high temperature incinerators with plasma torches): ash residue, off gases filters, scrub solutions
- Emulsification: alkaline aqueous waste, separated diluent
- Alkaline hydrolysis: alkaline aqueous waste, separated diluent

Secondary waste generated by **solid organic waste** treatment technologies:

Solid organic waste treatment and expected secondary waste	
High force compaction (super-compaction)	Liquid waste
Incineration, pyrolysis, plasma	Off gases, scrubbing solution
Metal melting	Off gases, slag
Molten salt oxidation	Slat residues, off gases
Thermochemical	Off gases

Treatment of LILW and decontamination processes can generate **off gasses** or release contaminants, this must also be treated and mitigated, leading to some secondary waste:

Gaseous and airborne waste treatment and expected secondary waste	
HEPA filtration	HEPA and pre-filter waste
Sorption, cryogenic trapping	Spent (degraded) sorption media waste

Wet scrubbing	A liquid waste stream

Many processes in the nuclear industry require cooling solution or cleaning steps using water. Contaminated **aqueous solutions** are treated to concentrate the activity in a smaller fraction and allow a large volume of clean water to be free released. Nevertheless, these treatments also produce some secondary waste:

Aqueous solution treatment and expected secondary waste	
Filtration	Filter media, cartridges and wash liquors
Chemical precipitation (coagulation, flocculation, separation)	Sludge, supernatant requiring further treatment
Evaporation	Evaporator concentrate, salt cake if addition drying, condensate requiring further treatment
Ion exchange (organic or inorganic ion exchange)	Spent organic ion exchangers, regeneration liquors for organic ion exchange resins
Membrane technologies (micro-, ultra-, nano-filtration, reverse osmosis)	Used membranes, concentrated streams
Biotechnological processes (biodegradation, biosorption, bioaccumulation)	Contaminated biomass, sludge

Radioactive waste streams also arise from pharmaceutical and medical applications that use radioelements and irradiation processes. Specific treatment technologies for **biohazardous radioactive waste** are commonly applied which also generated secondary radioactive waste:

Biohazardous radioactive waste treatment and expected secondary waste	
Incineration	ash, off gases, filters
Freezing / refrigeration	Liquid effluents
Steam autoclaving	Liquid effluents
Mummification: toxic chemicals liquid waste	Toxic chemicals liquid waste

Disinfection	Toxic chemicals liquid waste, off gases, solid organic waste
Chemical decomposition	Liquid waste
Maceration / pulverization	Liquid waste

With the expectation to reduce the volume of waste, radioactive solid materials are decontaminated allowing the free release of a large fraction of the initial volume. **Decontamination methods** are efficiently deployed for concrete materials and metallic waste, nevertheless secondary waste is generated and must be treated afterwards:

Decontamination methods and expected secondary waste	
Abrasive mechanical (brush, washing)	Dust and airborne, wastewater, abrasive and debris
Vibratory cleaning	Debris
Vacuum cleaning	Dust and contaminated filters
Steam jets, blasting	Wastewater, abrasive, debris
Gels	Organic or mineral compounds
Foams (spraying, sprinkling, filling with foam)	Toxic or corrosive solution or gases
Electrochemical methods	Hydrogen and contaminated acidic aerosols, iron phosphate sludge
Ultrasonic cleaning	Debris
Thermochemical	Slag containing the bulk of contamination

Secondary waste may be generated during processes involving HLW, for example the reprocessing of **Spent Nuclear Fuel.** Depending on the national policy, the reprocessing of spent nuclear fuel may be part of the management of nuclear waste. Focussing on predisposal activities, most of the secondary wastes generated during the conditioning of the LILW produced during the **conditioning** processes of High Level Liquid Waste from reprocessing, consists of filters, scrub solution, used melters and off gases. Amongst the conditioning processes, the most common are glass vitrification, the use of ceramics, cements and bitumen matrices. When spent nuclear fuel is not reprocessed, a possible option for its conditioning consists of the isolation in a multi-component barrier consisting of various metals and the packaging canister.

Whatever the type of primary waste and the process envisaged for its treatment, the importance of secondary waste should be emphasised when waste is treated in a remote facility as a service for waste for the owner. This is particularly the case when the primary waste has to be shipped to other sites, or even to another country, where the treatment facilities may be located. The management of secondary waste needs to be resolved and contractually covered, either considering the treatment of the secondary waste on-site together with the primary waste, or by returning it to the owner of the waste.

Another aspect in the planning and program initiation is the comparison of the processing options to minimize the volume of secondary waste(s) generated, ensuring a mature solution exists for their management.

During the planning and program initiation, Secondary Waste management issues closely link to the other EURAD Roadmap Domains Insights 2.1.1 – Inventory, 2.1.2 – Waste Acceptance Criteria, 2.1.3 – Technology selection, 2.1.4 – Waste hierarchy, 2.2.3 – Conditioning and 2.2.5 – Transport.

3.2 Program Implementation

Characterization of the secondary waste is a key activity in the implementation phase, in order to apply the most appropriate solution for their management in line with the application of the waste hierarchy (see also DIs 2.1.4 – Waste Hierarchy and 2.2.1 – Characterization for further information). During implementation the same recommendations and legislations apply as for primary waste streams (see also DIs 2.2.2 – Treatment and Processing, 2.2.4 – Storage for further information).

3.3 Program Operation and Closure

During operation of (pre-disposal) waste management facilities there is a continuous process of reviewing the management of radioactive waste. Annual reviews of on-site and centralized programmes should be conducted, as:

- Updates of the radioactive waste inventory are necessary ,
- New uses and procedures may alter the characteristics of the radioactive waste;
- Changes of regulations in Member States may require revisions of management procedures and strategies;
- Changes in volumes and composition of the radioactive waste may result in new pricing structures, or the final disposal route may increase its pricing structure, making use of that disposal route no longer viable.

4 CRITICAL ISSUES, INFORMATION, DATA OR KNOWLEDGE IN THE DOMAIN OF SECONDARY WASTE MANAGEMENT

Secondary radioactive waste management faces similar critical issues to the management of primary waste. This concerns:

- the type of processing option for the primary waste and the minimisation of the subsequent secondary waste.
- the nature of the materials: they have to be compatible with a mature technology option: several treatment technologies are already quite advanced (TRL 9) and are commonly deployed currently in multiple countries in a large number of nuclear plants.

5 MATURITY OF KNOWLEDGE AND TECHNOLOGY

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

Advances in secondary waste management

The entire life cycle of the of a process is taken into account to assess its potential environment impacts and related costs: Life Cycle Assessment (LCA) and Life Cycle Costing (LCC). The challenge of secondary waste must be included in such assessments and was included as part of the PREDIS activities.

Optimisation challenge and innovations

The optimisation challenge in the secondary waste management is directly connected with the optimisation and innovations in the management of LILW. The optimisation would be related to the development of new technologies for the treatment of primary wastes and decontamination activities. As an example, the segmentation process to cut metallic assemblies may be optimise using robotics and reduce secondary effluents.

Optimisation challenges and innovations in the reduction of the generation of secondary waste can be done by:

- improvements to water cleaning technologies
- decontamination systems to reduce waste volume
- concentration of sludge
- absorption of liquid allowing to dispose of solid waste
- absorption and removal of contaminant while releasing clean water

See DIs 2.2.1 – Characterisation and 2.2.2 – Treatment and Processing.

6 PAST RD&D PROJECTS ON SECONDRY WASTE MANAGEMENT

The problem of secondary waste management is usually associated with the management of the primary radioactive waste, far fewer projects or RD&D programs were devoted specifically to the management of secondary wastes.

Reduction on secondary waste generation: Modular/mobile effluent and waste retrieval plants. Nuclear Engineering Services (NES) is supplying Sellafield Ltd on behalf of the Nuclear Decommissioning Authority (NDA) with three silo emptying plant (SEP) Mobile Cave waste retrieval machines, for the removal of intermediate-level wastes (ILW) from the 22 silos.

(https://www.onr.org.uk/pars/2022/sellafield-21-016.pdf)

7 UNCERTAINTIES

The uncertainties in the secondary waste management are mainly associated with the management of the primary waste.

Technologies and good practices for radioactive waste management are quite advanced in many countries, nevertheless the activities should comply with the future technological development and the public acceptance.

8 GUIDANCE, TRAINING AND COMMUNITIES OF PRACTICE

This section provides links to resources, organisations and networks that can help connect people with people, focused on the domain of secondary waste management.

Guidance
• No guidance specifically related to secondary waste management. This activity is included in the various activities covered by the EURAD Roadmap Domain: Inventory, Technology Selection, Waste hierarchy, Characterisation, Treatment Processing, Conditioning and Packaging, Storage.
Training
As secondary radioactive waste management faces similar critical issues to the management of primary waste, training activities are those identified in the DI 2.2.2 – Treatment and Processing: • IAEA online learning courses on spent fuel and radioactive waste management, decommissioning and environmental remediation (link). • SCK CEN - Training course on radioactive waste management (link). • ENEN - Winter School on Nuclear Waste Safety and Management (link). • TÜV Italia Akademie - Nuclear Safety with Respect to Radioactive Waste Management Facilities (link). • EU - Summer School on Nuclear Decommissioning & Waste Management (ELINDER Course G5) (link).
Active communities of practice and networks
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Key competences that are needed in the area of secondary radioactive waste include radiation safety, material science for package integrity, logistics, radiological measurements and monitoring, data handling and preservation, risk management, scenario preparation, communication (stakeholder engagement), programme management.

9 ADDITIONAL REFERENCES AND FUTURE READING

IAEA-TECDOC-1817 - "Selection of Technical Solutions for the Management of Radioactive Waste", 2017 online

IAEA-TECDOC-655 - Treatment and conditioning of radioactive solid wastes (1992) online

IAEA-TECDOC-656 - Treatment and conditioning of radioactive organic liquids (1992) online

IAEA-TECDOC-1041 - Management of small quantities of radioactive waste (1998) online

IAEA-TECDOC-1130 - "Recycle and Reuse of Materials and Components from Waste Streams of Nuclear Fuel Cycle Facilities," 2000 online

IAEA TECHNICAL REPORTS SERIES No.402 - Handling and Processing of Radioactive Waste from Nuclear Applications (2001) online

IAEA-TECDOC-1336 - Combined methods for liquid radioactive waste treatment (2003) online

IAEA-TECDOC-1538 - Categorizing Operational Radioactive Wastes (2007) online

IAEA Safety Standards Series (2009):

- GSG-1: Classification of Radioactive Waste online
- GSG-5: Predisposal Management of Radioactive Waste online

EURAD ROUTES Deliverable D9.12 "Studies and plans for developing shared solutions for radioactive waste management in Europe" online

[OECD] – R&D and Innovations Needs for decommissing Nuclear Facilies, Radioactive Waste Management (2014)

ENER – ENER/2021/NUCL/SI2.853676 – "Study on radioactive waste classification schemes in the European Union" – Final report online