



2.2.2 Treatment & Processing

Domain Insight with EURAD Roadmap

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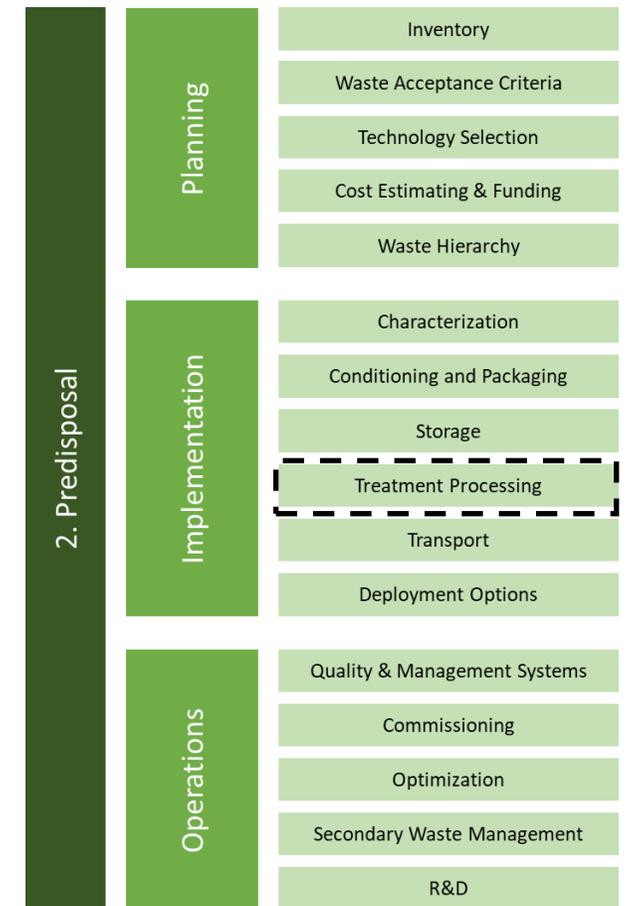
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Outline



Introduction to DI Treatment & Processing

- Treatment & Processing involve operations intended to change waste streams' characteristics to improve safety or economy.
- Processing actions includes pre-treatment and treatment. Secondary waste streams that may result from the processing of the primary waste stream must also be handled in a safe and efficient manner.
- The selection of the different approaches and technologies for waste treatment should take into consideration the characteristics of the waste and the demands imposed by the subsequent steps in its management (conditioning, transport, storage and disposal).



Typical overall goals and activities in the domain (Based on EURAD Roadmap GBS)

- Domain Goals:
 - Minimise the quantity and volume of radioactive waste through pre-treatment and treatment (Treatment & processing)
- Domain Activities:
 - Phase 1: Planning and Programme Initiation
 - Phase 2: Program Implementation
 - Phases 3-4: Program Operation / Optimisation and Closure

International Legislation

- There are no international legislations strictly related to the Treatment and Processing of radioactive waste. In general, with the [Directive 2011/70/Euratom], the EU establishes requirements for safe long-term management of radioactive waste.
- Generic Safety Requirements for Processing of radioactive waste are reported in the [IAEA GSR Part 5].
- Each Country has its own nuclear waste management policy and its national regulations that influence the approach taken for waste treatment.

Planning and Program Initiation

- Define the waste process route for any specific waste stream and estimate products and secondary waste arisings
- Evaluate spent fuel re-processing options as well as decontamination, free-release and recycling opportunities
- Compare processing technology options with respect to safety, economic and environmental life cycle parameters
- Identify processing facilities requirements and determine the need for transport and interim storage
- Evaluate the interdependencies between the different predisposal processing steps
- Understand regulatory requirements and prepare documentation for processing facility operation licensing

Program Implementation

- Getting closer towards actual operation of facilities and handling of radioactive waste streams, it is critical to schedule and design construction/modification of facilities or finalising contracts (for cross-border services), start with the actual treatment and processing and maintain detailed records of waste history, inventory and processing
- Radioactive waste should be processed as close to the point of generation as practicable considering different aspects, such as safety, security, exposure and financial aspects
- The processes to be employed should be selected based on the characteristics of the waste concerned. If possible, processes that achieve high volume reduction factors and that use proven techniques should be employed

Program Implementation

- Pre-treatment includes operations such as waste collection, segregation, chemical adjustment and decontamination.
 - Collection and segregation should be based on the radiological, physical and chemical properties of the waste and in accordance with the waste management programme (e.g. Combustible or non-combustible, if thermal treatment is a viable option; Compressible or non-compressible, if compaction is a viable option; Metallic or non-metallic, if melting is a viable option; Fixed surface contamination or non-fixed surface contamination, if decontamination is a viable option)
 - In the segregation of waste, it should be considered whether the waste can be cleared from regulatory control or whether it can be recycled or discharged, either directly or after allowing for a period of storage for radioactive decay

Program Implementation

- The treatment of radioactive waste may include the following:
 - Reduction in the volume of the waste (e.g. by incineration of combustible waste, compaction of solid waste and segmentation or disassembly of bulky waste components or equipment)
 - Removal of radionuclides (e.g. by evaporation or ion exchange for liquid waste streams and filtration of gaseous waste streams)
 - Change of the form or composition of the waste (e.g. by means of chemical processes such as precipitation, flocculation and acid digestion, as well as by chemical or thermal oxidation)
 - Change of the form or properties of the waste (e.g. solidification, sorption or encapsulation; common immobilization matrices include cement, bitumen and glass)
- Treatment includes also spent fuel re-processing option

Program Operation and Closure

- Manage iterative reviews and updates of processing plans and methods
- Ensure responsible management of secondary waste streams produced during processing
- Responding to latest RD&D and technology development
- Responding to regulatory and waste acceptance requirements update

Critical issues, information, data or knowledge in the domain of Treatment & Processing

- The nature of the material to be processed: all properties of the radioactive waste that may affect safety during processing should be considered
- The type of processing option: all relevant factors (e.g. nuclear and radiation safety, discharges, minimisation of secondary waste, ability to apply quality assurance, etc) should be considered when selecting the processing options
- The type of treatment facility (permanently installed/mobile/off-site): the opportunity to implement mobile or off-site services/facilities for processing waste, should be considered based on quantities, dimensions, waste routes and regulatory requirements
- The design of the process (single step/multi step): the properties of the processed waste (e.g. radiological, physical, chemical, biological, geometrical, traceability/labelling) during the different phases should be defined and controlled to ensure the compatibility with the subsequent steps of waste management.

Future advances

- Management of problematic waste:
 - Graphite mixed waste
 - Organic materials: Research activities related to alternative thermal treatment technologies. Develop alternative solutions for ^{14}C
 - Reactive metallic waste, including dust (hydrogen in disposal environment)
 - Liquid waste with specific contaminants
 - Hazardous and toxic materials (e.g. asbestos and Polychlorinated Biphenyls (PCBs))
- New and emerging solutions:
 - High efficiency and reduction of secondary waste
 - Industrialisation of lab scale solutions
 - Information Technology (IT) tools and other emerging technologies to manage waste flows from production to disposal
 - Solutions for new fuel types and advanced reactors/fuel cycles

Future optimisation challenges and innovations

- Flexible decontamination and treatment processes (including modular and mobile systems):
 - Treatment solutions for different quantities, dimensions, characteristics, waste routes and regulatory requirements
 - Benchmarking for decontamination technologies and approaches (good efficiency and minimised secondary waste production)
 - Promote international sharing of facilities
- Recycling and reuse:
 - Benchmarking of technologies
 - Regulatory requirements for release
 - Societal engagement for recycling
 - Harmonise good practices in recycling of released materials

Past RD&D projects on Treatment & Processing

- FP7 EURATOM - **CARBOWASTE** (2008-2013): The Treatment and Disposal of Irradiated Graphite and other Carbonaceous Waste (CARBOWASTE) project was focused on the development of guidelines to support the retrieval, treatment and disposal of irradiated graphite.
- H2020 - **THERAMIN** project (2017-2020): The objective of the Thermal Treatment for Radioactive Waste Minimisation and Hazard Reduction (THERAMIN) project was to provide improved safe long-term storage and disposal of intermediate-level wastes (ILW) and low-level wastes (LLW) suitable for thermal processing.
- EJP **EURAD** (2019-2024): Among the different WPs of the EU Joint Programme on Radioactive Waste Management (EURAD), WP9 (ROUTES) of EURAD has the aim to describe and compare the different approaches to characterisation, treatment and conditioning and to long-term waste management routes between MS (member states) to identify relevant R&D topics which could be collaboratively launched in the second wave of EURAD. [EURAD ROUTES D9.12] summarises the knowledge and approaches regarding the sharing of technology and facilities between countries in different steps of the waste lifecycle.
- HORIZON EUROPE – **HARPERS** (2022-2025): The overall goal of the HARPERS “HARmonised PracticEs, Regulations and Standards in waste management & decommissioning” project is to establish and clarify the benefits and added value of more aligned and harmonised regulations, practices and standards in decommissioning and radioactive waste management, including possibilities for shared processing, storage and disposal facilities between Member States.

Uncertainties

- Technologies and practices for radioactive waste treatment and processing are quite advanced with minimal uncertainties. Existing guidance provides a good basis for waste processing.
- Variability of WAC between different countries translate in the difficulty for different countries to apply the same treatment processes, because the final waste form (or the secondary wastes) doesn't comply with the WAC for the disposal or storage.
- There are still challenges for countries with less advanced/small programmes to realise treatment and processing facilities when small quantities of waste need to be treated. Opportunities exists for further develop cross-border services and shared facilities.
- Some challenging waste streams (e.g. graphite, organic waste, reactive metals and future generation wastes, like molten salt reactors) have not yet a mature and consolidated treatment technologies. RD&D activities are needed to develop solutions for such problematic waste management.
- Further optimisation of technologies and approaches can bring more economical, sustainable and environmentally-friendly waste treatment and processing practices.

Guidance, training and communities of practice

Guidance

- IAEA Safety Guide GS-G-3.3 - The Management System for the Processing, Handling and Storage of Radioactive Waste (2008) - [online](#)
- IAEA General Safety Requirements GSR Part 5 – Predisposal Management of Radioactive Waste (2009) - [online](#)
- IAEA General Safety Guide GSG-3 - The Safety Case and Safety Assessment for the Predisposal Management of Radioactive Waste (2013) - [online](#)
- IAEA Specific Safety Guide SSG-40 - Predisposal Management of Radioactive Waste from Nuclear Power Plants and Research Reactors (2016) - [online](#)
- IAEA Specific Safety Guide SSG-41 - Predisposal Management of Radioactive Waste from Nuclear Fuel Cycle Facilities (2016) - [online](#)
- IAEA Safety Guide SSG-45 - Management of Radioactive Waste from the Use of Radioactive Material in Medicine, Industry, Agriculture, Research and Education (2019) - [online](#)
- NEA - Recycling and Reuse of Materials Arising from Decommissioning of Nuclear Facilities, NEA No. 7310 (2017) - [online](#)
- NEA - Optimising Management of Low-level Radioactive Materials and Waste from Decommissioning, NEA No. 7425 (2020) - [online](#)

Guidance, training and communities of practice

Training

- IAEA – online learning courses on spent fuel and radioactive waste management, decommissioning and environmental remediation. Pre-disposal waste management topical courses (including waste processing) are under preparation. [link](#)
- Training courses on Radioactive Waste Management:
 - 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

- World Nuclear Association - Waste Management & Decommissioning Working Group - “Methodology to Manage Material and Waste from Nuclear Decommissioning”, 2019 – [online](#) - outlines international good practice and gives details on potential methodologies

Additional references and future reading

- European Union Council Directive 2011/70/Euratom (2011). Establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste [online](#)
- IAEA-TECDOC-1817 - “Selection of Technical Solutions for the Management of Radioactive Waste”, 2017 [online](#)
- PREDIS Strategic Research agenda (SRA) [online](#)
- EURAD ROUTES Deliverable D9.12 “Studies and plans for developing shared solutions for radioactive waste management in Europe” [online](#)
- Several technical documentations are available for future reading to provide Member States with experiences and lessons learned on specific treatment topics:
 - 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-1371 - Selection of efficient options for processing and storage of radioactive waste in countries with small amounts of waste generation (2003) [online](#)
 - IAEA Technical Reports Series No.427 - Predisposal Management of Organic Radioactive Waste (2004) [online](#)
 - IAEA-TECDOC-1527 - Application of Thermal Technologies for Processing of Radioactive Waste (2006) [online](#)
 - IAEA Nuclear Energy Series – Technical Reports Guides No. NW-T-1.7 “Waste from Innovative Types of Reactors and Fuel Cycles - A Preliminary Study”, 2019. [online](#)

Figures



Solid waste super-compaction

<https://world-nuclear.org>



Ion exchange Cesium-removal system

<https://www.nuclearsolutions.veolia.com>



Media blasting of metallic components

PreussenElektra GmbH, Würgassen nuclear power plant

Figures



Incineration plant

<https://www.javys.sk>



Plasma plant

<https://www.zwilag.ch>



Metal melting

<https://www.cyclife-edf.com>