TREATMENT & PROCESSING; DOMAIN INSIGHT 2.2.2

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OVERVIEW

Radioactive wastes produced from the operation and decommissioning of nuclear facilities and from the application of radionuclides in industry, medicine and research, must be handled and processed in a manner that protects human health and the environment, now and in the future, without imposing undue burdens on future generations.

Processing actions includes pre-treatment (such as minimisation), treatment (such as by reprocessing of spent fuel, thermal or chemical processes of wastes) and conditioning (such as immobilisation). 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 final goal is to minimise the quantity and volume of radioactive wastes and put them into a form that is suitable for disposal, where routes are readily available, or for long-term storage (ref. DI Storage) pending the development of suitable disposal routes.

This Domain Insight document includes pre-treatment and treatment processing steps, while conditioning has his own Domain (i.e., Domain 2.2.3) .

Pre-treatment is defined as the operations preceding waste treatment and it may include operations such as waste collection, segregation, chemical adjustment and decontamination with the aim of reducing the amount of radioactive waste and/or adjusting its characteristics to make it more amenable to additional processing and disposal.

Treatment of radioactive waste has the aim of reducing the potential hazard of the waste (radiological hazard but also chemical (e.g. explosive, burnable, corrosive, etc.), pathogenic or other hazards associated with the waste) and enhancing safety in the long term (as one of a series of steps contributing to the safe predisposal management of radioactive waste).

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Three basic treatment objectives are:

- volume reduction;
- removal of radionuclides;
- change of physical state and chemical composition of the waste.

The selection of the different approaches and technologies for waste treatment should be based on appropriate consideration of the characteristics of the waste and of the demands imposed by the subsequent steps in its management (conditioning, transport, storage and disposal).

Due to the fact that radioactive waste is diverse and varied in nature and it encompasses a broad range of radionuclides, half-lives, activity concentrations, volumes and physical and chemical properties (other than radionuclides, the waste may contain other hazardous elements (i.e. asbestos, mercury, beryllium, cadmium), the choice of process(es) to be used for waste treatment is complex.

KEYWORDS

predisposal, processing, treatment, pre-treatment, radiation protection, safety

KEY ACRONYMS

GBS – goals breakdown structure
EU – European Union
GSR – General Safety Requirements
RD&D – Research, Development and Demonstration
SRA – Strategic Research Agenda
PCBs – Polychlorinated Biphenyls
POCO – Post Operational Clean-Out
TRL – Technology Readiness Level
HLW – High Level Waste
ILW – Intermediate Level Waste
LLW – Low Level Waste
IT – Information Technology
WAC – Waste Acceptance Criteria

1 TYPICAL OVERALL GOALS AND ACTIVITIES IN THE DOMAIN OF TREATMENT AND PROCESSING

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	
2.2.2 Minimise the quantity and volume of radioactive waste through pre-treatment and treatment (Treatment & processing)	
Domain Activities	
Phase 1: Planning and Programme Initiation	Definition of the waste process route for any specific waste stream and estimation of products and secondary waste arisings. Evaluate spent fuel re-processing options as well as decontamination, free-release and recycling opportunities (see DI Waste Hierarchy). 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 (link with Transport and Storage Domain Insights) Evaluate the interdependencies between the different predisposal processing steps (link with Conditioning and Waste Acceptance Criteria Domain Insights). Understand regulatory requirements and prepare documentation for processing facility operation licensing.
Phase 2: Program Implementation	Schedule and design construction/modification of facilities and/or finalising cross-border services. Conduct the actual processing actions (pre-treatment and treatment). Maintain detailed records of waste history, inventory and processing.
Phases 3-4: Program Operation/Optimisation and Closure	Manage iterative reviews and updates of processing plans and methods. Ensure responsible management of secondary waste steams produced during processing.

	Responding to latest RD&D and technology development. Responding to regulatory and waste acceptance requirements update.

2 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 and it is built on a series of internationally accepted principles, in particular that present and future generations shall be protected without imposing undue burdens on future generations.

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.

3 GENERIC SAFETY ISSUES FOR TREATMENT AND PROCESSING

This section describes the safety precautions associated with radioactive material treatment and processing 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 shall be noted that safety and regulation issues for treatment and processing 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 assess the present and future waste inventory and establishing waste management priorities based on an understanding of potential Environmental, Health, and Safety risks and impacts and considering waste generation and its consequences.

A waste management hierarchy that considers prevention, reduction, reuse, recovery, recycling, removal and finally disposal of wastes has to be well established. This includes also opportunities for spent fuel re-processing. Defining a spent fuel management policy is an essential step for each country and the choice for reprocessing depends on the national boundary conditions. **The** necessary technical and financial resources need to be available for the safe and responsible management of spent fuel. Irrespective of which option is chosen, a deep geological repository will be needed for some waste streams.

In selecting the waste processing strategy, quantities, activity and physical and/or chemical nature of the radioactive waste to be treated have to be considered. The generation of secondary waste materials has to be avoided or minimised as far as practicable.

In deciding on treatment processes, consideration should be given to the suitability of the resultant waste to subsequent conditioning step. Moreover, requirements for transport and storage, including retrieval, should be includes and also compliance with the final disposal waste acceptance criteria.

The most appropriate treatment and conditioning options are those that lead to a waste form and package that meets the acceptance requirements of the disposal facility, whilst minimising waste volumes and doses resulting from these operations.

Processing facilities need to be identified. This may include the possibility of sending the waste abroad for treatment (cross-border services), reuse of existing/modified facilities (on-site or in different locations) or building new facilities/plants (even mobile unit).

The need for buffer storage for the processing facility has to be determined as well as the needs for transport and interim storage of waste and packages.

During the planning phase, Treatment and Processing issues closely link to the other EURAD Roadmap Domains of Inventory (2.1.1), Waste Acceptance Criteria (2.1.2), Waste Hierarchy (2.1.4), Conditioning (2.2.3), Transport (2.2.4) and Storage (2.2.5).

3.2 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.

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.

Pre-treatment includes operations such as waste collection, segregation, chemical adjustment and decontamination.

Collection of waste and segregation should be performed on the basis of its radiological, physical and chemical properties. For example, solid waste should be segregated in accordance with the waste management programme, considering the following properties:

- Combustible or non-combustible, if thermal treatment (e.g. incineration) 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.

By applying 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.

Spent sealed sources should be segregated from other waste and special care should be taken in the segregation of materials and objects that are fissile, pyrophoric, explosive, chemically reactive or otherwise hazardous, or that contain free liquids or pressurised gases.

Mixing of waste (e.g. for purposes of concentration averaging) at the point of generation may be allowed but considerations should be given to the radiological and chemical compatibility and to the required criteria for the subsequent processing step.

Decontamination is a pre-treatment process that allows the removal of surface contamination using a combination of mechanical, chemical and electrochemical methods. Care should be taken to limit the amount of secondary waste generated and to ensure that the characteristics of secondary waste are compatible with subsequent steps in the waste management process.

Typical decontamination methods [IAEA-TECDOC-1817] are:

- Mechanical decontamination methods
  - Swabbing, washing, scrubbing, brushing
  - Vibratory cleaning
  - Vacuum cleaning
  - Water and steam jets
  - Blasting
- Chemical decontamination methods
  - By chemical gels
  - By foams (spraying, sprinkling, filling with foam)
- Decontamination of surfaces by electrochemical methods (electro-polishing)
- Decontamination of surfaces by ultrasonic cleaning
- Thermochemical decontamination

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 immobilisation matrices include cement, bitumen and glass)

Treatment includes also spent fuel re-processing option. Based on the closed cycle, following the interim storage of the spent fuel in the reactor pools for some years to cool down the fuel, it is transferred to a reprocessing plant where the re-usable

components are separated from the residual waste products. The waste products ('high level waste' or 'HLW') needs to be conditioned, e.g. by vitrification, and transferred to a facility for interim storage, pending geological disposal. The separated energetic components can be used for fabrication of recycled fuel to be re-used in a thermal neutron reactor or in a fast neutron reactor.

For the processing of solid Low and Intermediate Level Waste [IAEA-TECDOC-1817], many solutions are available:

- Compaction
  - Low force compaction
  - High force (super) compaction
- Thermal treatment methods
  - Incineration
  - Pyrolysis
  - Plasma
  - Metal melting
- Emerging
  - Molten salt oxidation
  - Thermochemical

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. Considerations should be given to the releases of radionuclides and other non-radiological hazards to the environment (e.g. in case of incineration) and to prevent the spread of particulate contamination in case of segmentation techniques.

Methods for the treatment of aqueous waste [IAEA-TECDOC-1817] include:

- Filtration
- Chemical precipitation (coagulation/flocculation/separation)
- Evaporation
- Ion exchange
  - Organic ion exchange
  - Inorganic ion exchange
- Membrane technologies
  - Ultrafiltration
  - Nanofiltration
  - Reverse osmosis
- Biotechnological processes (biodegradation, biosorption, bioaccumulation)

In each case, limitations on processes that may be associated with corrosion, scaling, foaming and the risk of fire or explosion in the presence of organic material should be carefully considered, especially about the safety implications of operation and maintenance.

Organic waste requires management steps that take account not only of its radioactivity, but also of its chemical organic content, since this can also have detrimental effects on the environment. Typical treatment technologies for liquid organic waste [IAEA-TECDOC-1817] are:

- Distillation
- Liquid–liquid extraction
- Absorption

- Incineration (including conventional incinerators – starved air, excess air, rotary kilns and high temperature incinerators with plasma torches)
- Emulsification
- Alkaline hydrolysis

Treatment systems for gaseous radioactive waste should take into consideration: the amount of gas to be treated, its activity, the radionuclides contained in the gas, the concentrations of particulates, the chemical composition, the humidity, the toxicity and the possible presence of corrosive or explosive substances. Radioactive particulates and aerosols in gaseous effluents may be removed by filtration using HEPA filters. Other types of filters and scrubbers can be used to remove specific components, gaseous chemicals, particulates and aerosols from off-gases.

Both liquids and gases could be potentially discharged in the environment within authorised limits. The discharging process must be approved by the regulatory body after the submission of an environmental impact assessment and the definition authorised limits on discharges.

During the implementation phase, Treatment and Processing issues closely link to the other EURAD Roadmap Domain of Conditioning (2.2.3), Transport (2.2.4) and Storage (2.2.5).

3.3 Program Operation and Closure

During operation of (pre-disposal) waste management facilities there is a continuous process of reviewing treatment and processing plans and methods. There are opportunities to take into practice new technologies and practices to improve performances, increase efficiency and reduce volume of waste to be disposed. Optimisation of processing route for cost and safety can be enhanced.

Regulatory oversight will continue to evaluate treatment and processing of radioactive waste, including issues like:

- compliance with safety precautions towards the public and environment,
- compliance with the Waste Acceptance Criteria for subsequent processing steps (e.g. conditioning) and for interim stores or disposal sites. This also includes the potential need for re-processing of wastes in interim storage to fulfil updated final disposal requirements or repository detailed designs,
- documentation of the waste processing parameters and waste package characteristics,
- safety and operational performance of the processing facilities and equipment,
- accurate characterisation and classification of secondary waste and materials recovered for reuse.

At the end of operations, it will be evaluated the opportunity of extending the facility life for treatment of other types of waste or consider the facility end of life and produce Post Operational Clean-Out (POCO) and decommissioning strategy/plans.

During the operation phase, Treatment and Processing issues closely link to the other EURAD Roadmap Domain of Waste Acceptance Criteria (2.1.2), Quality & Management Systems (2.3.1) and Optimisation (2.3.2).

4 CRITICAL ISSUES, INFORMATION, DATA OR KNOWLEDGE IN THE DOMAIN OF TREATMENT AND PROCESSING

Although the safety objective of waste treatment is the same, the means of achieving it may differ considerably depending on the type and amount of waste to be treated as well as the type of process (e.g. vitrification vs. simple packaging). The requirements should accordingly be implemented using a graded approach proportionate to the hazard of the process and the radioactive waste.

The main critical issues related to the Treatment and Processing domain are referred to:

- the nature of the material to be processed: in addition to radioactivity, 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): considerations should be given to the opportunity to implement mobile solutions for processing waste including quantities, dimensions, waste routes and regulatory requirements. Additional safety issues could be associated with mobile equipment
- the design of the process (single step/multi step): depending on the specific waste management system, the treatment process may be a multistep process with one or more interim phases. 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.

Technologies, equipment, and processes for radioactive waste treatment are quite advanced (TRL-9). There are major treatment technologies (e.g. compaction/supercompaction, chemical precipitation, incineration, melting, material decontamination, etc.) which are commonly used at the present time in multiple countries or in a large number of nuclear plants.

In most of the cases, due to the fact that one plant doesn't produce sufficient volumes of waste to justify the large expenditures required for some high efficiency technologies (e.g. incineration or metal melt facility) the solution is to use a regional, centralised, off site processing facilities which accept waste from many nuclear plants. These facilities may be used for any individual country or they can also offer cross-border services and collaboration to international countries.

Another solution could be the use of mobile systems which can be transported among multiple nuclear sites for processing campaigns. Typically, such a system might be at an individual site for one to three months, but in some situations the mobile system may remain at an individual site for several years (e.g. the use of a supercompactor to recover some of the storage capacity of a ten-year accumulation of drummed and stored waste).In the design and operation phases the licensee is the main responsible for operational safety and product quality. Mobile processing equipment shall have clearly defined, safe interfaces to the hosting facility and the licensee shall provide a safety case for the use of the mobile waste processing equipment. The safety case shall consider among other things the installation,

maintenance, decontamination and de-installation phases, as well as the operational phase.

5 MATURITY OF KNOWLEDGE AND TECHNOLOGY

This section provides an indication of the relative maturity of information, data and knowledge for the domain of treatment and processing. It includes the latest developments [PREDIS SRA] for the most promising advances, including innovations at lower levels of technology maturity, where ongoing RD&D, Strategic Studies and Knowledge Management activities continue to improve.

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

Management of problematic waste:

- Graphite mixed waste
- Organic materials: Research activities related to alternative thermal treatment technologies. Develop alternative solutions for 14C
- 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))

Recycling and reuse:

- Benchmarking of technologies
- Regulatory requirements for release
- Societal engagement for recycling
- Harmonise good practices in recycling of released materials

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

6 PAST RD&D PROJECTS ON TREATMENT AND PROCESSING

Past and on-going European Commission funded projects and other international initiatives that have partially addressed radioactive waste treatment included:

- 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.

7 UNCERTAINTIES

Technologies and practices for radioactive waste treatment and processing are well 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.

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 treatment processing.

Guidance

The IAEA and NEA provide Member States with guidance on radioactive waste management based on the principle of radioactive waste minimisation.

- 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

Training

- The IAEA offers 12 online learning courses on spent fuel and radioactive waste management, decommissioning and environmental remediation. These courses consist of 50 modules and almost 100 lectures. They are free of charge and intended for anyone looking to understand the fundamentals of these topics, including young professionals and new entrants to the respective areas. link
  Specific e-learning modules for Radioactive waste treatment are under preparation.
- Training courses on Radioactive Waste Management are organised by different organisations and they also include treatment and processing topics. Some of them are here reported:
  - 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 monitors developments and shapes industry positions with a view to improving the system of waste management and decommissioning. It promotes the appropriate re-use and recycling of material – and safe disposal of waste – from nuclear sites.
  In 2019 a report that highlights the key principles and stages of efficient waste management processes and good practices was published: "Methodology to Manage Material and Waste from Nuclear Decommissioning", 2019 online

Key competences that are needed in the area of radioactive waste treatment and processing include radiation safety, waste chemistry, material handling, waste treatment, radiological measurements and monitoring, data handling and preservation, risk management, scenario preparation, safety case development, communication (stakeholder engagement), programme management.

9 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