



PREDIS

2.1.4 Waste Hierarchy

Domain Insight with EURAD Roadmap

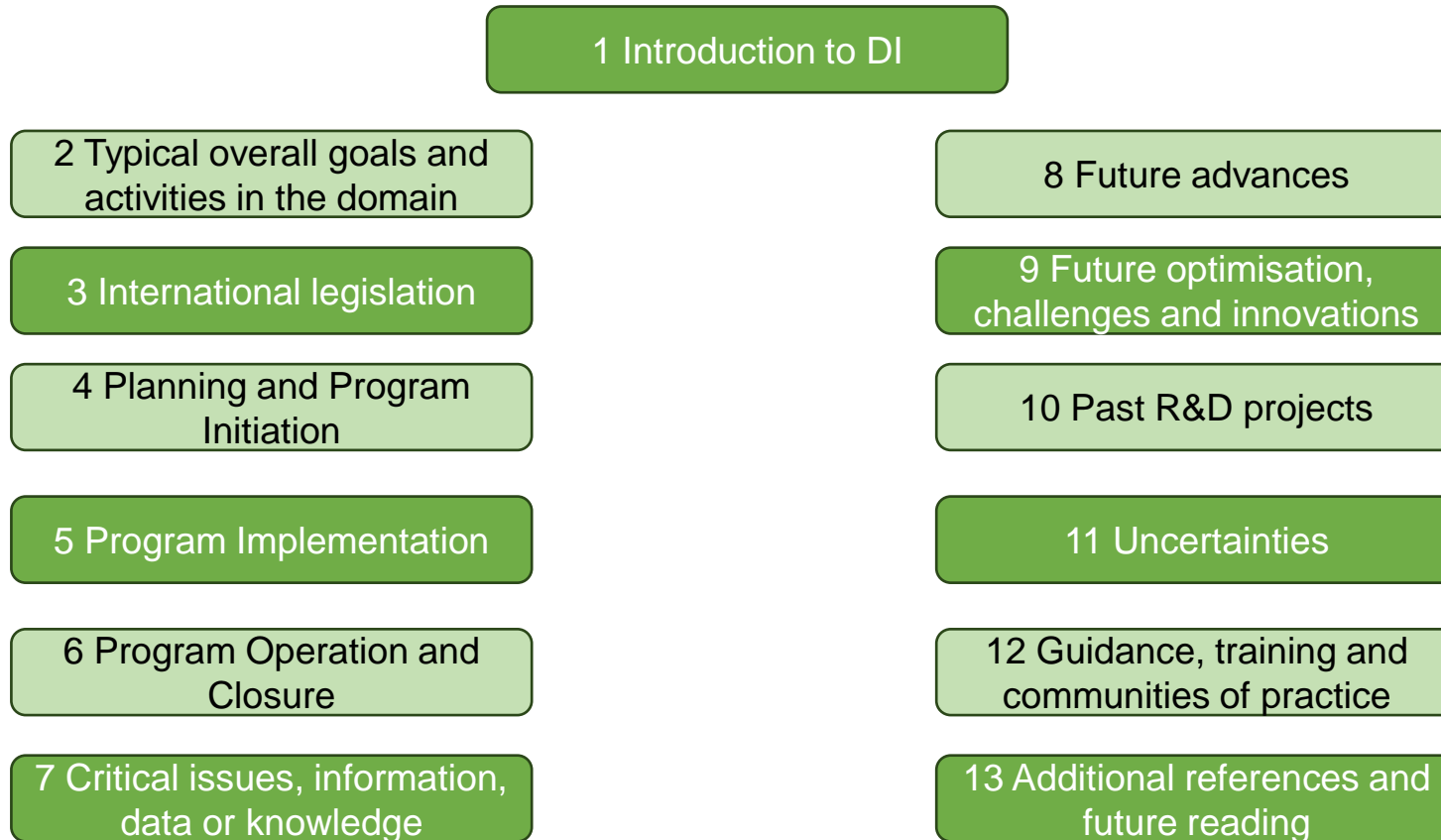
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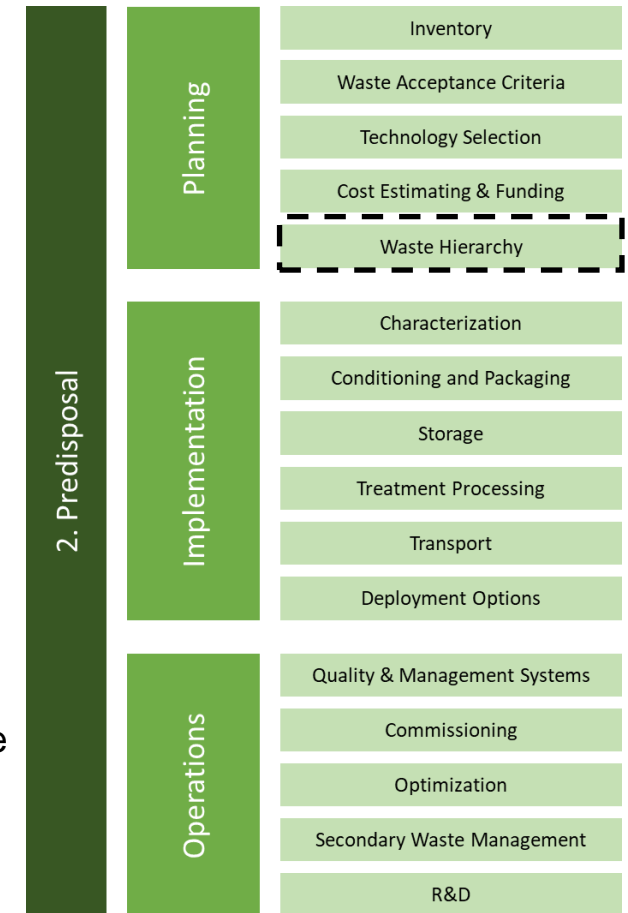
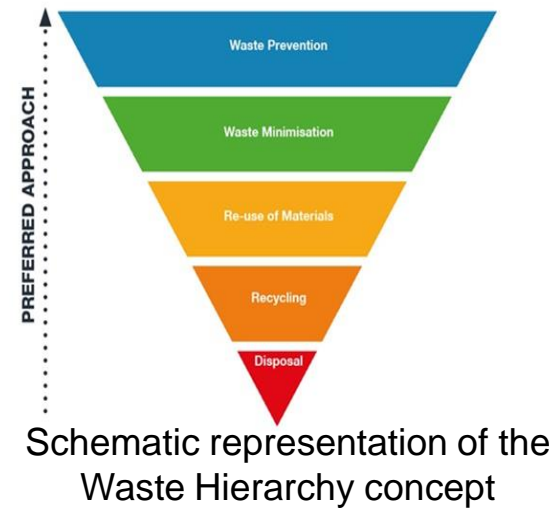
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Outline



Introduction to DI 2.1.4

- Radioactive waste management controls and accounts for waste to protect humans and the environment now and in the future.
- Waste Hierarchy (WH) is a stepwise approach to achieving waste minimisation to promote sustainability first introduced by the EU in 1975.
- It promotes managing waste in the following order of priority:
 - Prevention:** Prevent or reduce at source, the creation of waste.
 - Minimisation:** Reduce volume and/or radioactivity content of waste generated.
 - Reuse:** Where appropriate, waste materials or products should be reused directly or refurbished then reused.
 - Recycling:** Waste materials should be recycled or processed into a form that allows them to be utilized as a secondary raw material.
 - Other recovery:** Waste material is used to replace other materials that are used to fulfil other functions e.g. energy recovery.
 - Disposal:** Only if waste cannot be prevented, reused, recycled, or recovered should it be disposed of into the environment.



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

■ Domain Goal

Evaluate options to apply waste hierarchy to minimise waste volumes at higher impact inventory disposal levels.

■ Domain Activities

■ Phase 1: Planning and Programme Initiation

Consider full 'life cycle' of the processes; establish the types, quantities and locations of potential waste arisings and existing stored waste. Look at the other EURAD Roadmap Domains of (CFR, 2023)(Inventory, Characterisation).

Determine waste treatments / conditioning to be used and opportunities to prevent, reduce minimise, reuse, or recycle material or recover other value rather than disposal. Consider segregation in line with radiological classification. Ensure processes are considered 'Good Practice'.

Assess safety and stakeholder requirements.

Produce Product & Secondary Waste Plan (PSWP), Project Implementation Plan (PIP) and programme.

Consider facility end of life and produce Post Operational Clean-Out (POCO) and decommissioning strategy/plans.

Domain Activities contd.

- **Phase 2: Programme Implementation**

Identify facility requirements – can existing facilities/plant (modified if necessary) be used or will new facilities/plant be needed?

Schedule and design construction/modification of facilities.

Estimate throughputs and produce master flow diagram to demonstrate waste minimisation, understand products and secondary waste arisings. Determine the ability to utilise recovered, recycled materials, energy etc in other processes; review against PSWP and revise accordingly.

Determine provision for interim storage and ultimate disposal of material including arrangements for transferring between facilities and sites. Consider the requirements of other EURAD Roadmap Domains of Transport (2.2.5), Storage (2.2.4), Disposal)

- **Phases 3–4: Programme Operation/Optimisation and Closure**

Complete construction of facilities/plant identified in PIP, commission facilities and commence operations.

Undertake regular iterative reviews of operational performance against the PSWP and application of the waste hierarchy. Determine if waste minimisation and material recovery objectives are being met. Respond to latest RD&D, technology development, changes in international requirements, site licenses etc.

At end of operations review proposed POCO/Decommissioning strategy/plans against operational history and revise as necessary.

Implement POCO/Decommissioning strategy/plans.

International Legislation

- Waste treatment must be carried out in accordance with Articles 4 and 13 of the European Directive 2008/98/EC on Waste (the Waste Framework Directive). This directive fully embraces the need to apply the Waste Hierarchy.
- The requirements for waste prevention have been strengthened in EU Directive 2018//851.
- Principles adopted across the EU and associated countries e.g. in UK the legal requirement to apply the waste hierarchy was enshrined in law through the Waste (England and Wales) Regulations 2011.
- In 2016, the waste hierarchy was included in the 12th Sustainable Development Goals (SDG) of the 2030 Agenda for Sustainable Development adopted by the 193 United Nations countries.

For further information, please also see complimentary information from other EURAD Roadmap Domain Insights of Inventory (2.1.1), Waste Acceptance Criteria (2.1.2), Characterisation (2.2.1), Treatment & Processing (2.2.2), Conditioning (2.2.3), Storage (2.2.4) Transport (2.2.5).

Planning and Programme Initiation

- The pre-disposal program initiation must consider the full 'life cycle' of processes that may produce waste and what treatment or conditioning can be used. This allows an inventory to be established of anticipated types, quantities and locations of potential waste arisings and existing stored waste.
- Key steps are:
 - Identify opportunities to prevent, reduce, reuse, or recycle the waste material or recover other value from it before committing the minimal amount of waste for disposal.
 - Assess safety, regulator/stakeholder requirements, and whether potential segregation, treatment or conditioning will be safe (e.g. ALARP) with acceptable environmental impact.
 - Produce Product & Secondary Waste Plan (PSWP), Project Implementation Plan (PIP) and programme.
 - Produce strategy/plans for Post Operational Clean-Out (POCO) and decommissioning of facilities at end of operations and end-state of site/s.
- These steps must reflect good practice and utilise the waste hierarchy philosophy.

Programme Implementation

- Review inventory and existing process to identify opportunities for application of WH techniques:
 - to reduce waste arisings
 - to identify what could be recovered for recycle or reuse
 - to ensure that different classes of radioactive waste (i.e. exempt, VLLW, LLW, ILW and HLW) are separated
 - to ensure 'Good Practice' is being applied, i.e. Best Available Techniques (BAT) employed
- Identify facility requirements to implement WH e.g., facilities to segregate and hold different categories of waste, installation of decontamination capabilities and new treatment processes to modify the waste or separate out components for reuse/recycle.
- Determine if WH processing be met through use of existing and modified plant or will new facilities/plant be needed. Schedule and design construction or modification of facilities.
- Determine provision for interim storage and for transferring recovered materials for reuse applications whether that be recycled on site or exported off site; including ultimate disposal of any residual waste.
- Estimate throughputs and produce master flow diagram to demonstrate WH is being applied, understand products and secondary waste arisings. Determine the ability to utilise recovered, recycled materials, energy etc in other processes; review against PSWP and revise accordingly.

Programme Implementation- contd.

- Understand waste handling requirements and crucially how the waste material may change during each handling or treatment operation.
- Prior to movement of radioactive materials, ensure safety and quality plans meet regulatory requirements. The safety plan must ensure that no harm is done to operators or the environment, whilst the quality plan ensures the efficiency of the process, compliance with Waste Acceptance Criteria (WAC) for subsequent processing, storage, or ultimate disposal and that the aspirations of the Waste Hierarchy will be met.
- In the same way that waste packages typically have a Certificate of Compliance (CoC) from which it can be evaluated if further testing or maintenance is required, any recovered material intended for reuse needs to meet the specifications of subsequent processes.
 - Confirm chemical composition and physical characteristics include radiation measurements to ensure that it can be handled in downstream operations, especially if those processes are non-nuclear.
 - Consider using decay storage to allow short-lived radioactivity to decline so that the material meets the Acceptance Criteria for future use or disposal.
- Document possible safety risks and scenarios, including consequence assessments for hypothetical accident cases.

Programme Operation and Closure

- During operations ensure there is a continuous process of reviewing operational performance against the PSWP and application of the WH - are waste minimisation and material recovery objectives are being met.
- The operations should respond to the latest RD&D, technology development, changes in international requirements, site licenses etc. This and other external changes (e.g. new demand for materials) may give new opportunities to reduce future waste arisings or recover additional materials that were not envisaged initially.
- Throughout the operational life of the regulatory oversight requires that evidence is retained of the performance of the plant and any modifications made. For WH this means:
 - documentation of the radioactive material processed, conditions used and where it has been transferred to,
 - accurate characterisation and classification of materials recovered for reuse,
 - accurate markings and labelling imposed on wasteforms and packages,
 - verifying the recovered materials are safe for use; i.e. Recovered materials comply with specifications for reuse, wasteforms/packages meet WAC for storage or disposal.

Programme Operation and Closure- contd.

- At the end of operations, it will be necessary to review the original POCO/Decommissioning strategy/plans against operational history and revise them as necessary to respond to changes in the plant over time along with any changes in legislation or improvements in treatment technology.
- During the decommissioning, the plant/facility structural materials and equipment dismantled should continue to adhere to WH. Throughout this phase the revised POCO/Decommissioning strategy/plans should be regularly reviewed to ensure best practice is being employed and any new opportunities to improve on the WH performance are realised.

Critical issues, information, data or knowledge in the domain of Waste Hierarchy

- The WH is an approach developed for the management of general waste and not specifically for radioactive waste.
- It is enshrined within the laws and regulations of EU countries, and affiliates e.g. EFTA and the UK. Derived from a single set of EU directives, the regulations are implemented at a national level, which leads to some inconsistency within and across borders
- Compliance with the Environmental Waste Hierarchy (EWH) has increased over time.
 - Waste Electrical and Electronic Equipment (WEEE) directive
 - Restriction of Hazardous Substances (RoHS) Directive
 - European strategy for recycling plastic materials
- Commercial and socio-economic pressure to apply WH.
- Support from general waste trade association (e.g. WFAA, CIWM & ISWA).
- The ERDO Association is specifically focused on radioactive waste (<https://www.erdo.org/>).
- WH versus Circular Economy approach – both support waste minimisation.

Future advances

- New or improved technologies related to handling or processing materials that are being implemented for non-radiological waste or developed specifically for the radioactive waste domain become available for general use; examples include:
 - Use of robotics and improved automated separation techniques (such as AI driven autonomous recognition of components) would significantly reduce operator dose and allow more segregation to be undertaken.
 - Improved decontamination or chemical separation processes will allow more materials extracted for reuse.
 - Utilisation of a decay storage regime to allow materials to be downgraded to lower radiological category and or permitted for free release.

Future optimisation challenges and innovations

- Life Cycle Analysis (LCA) has heightened awareness of the environmental impact of waste generation and the benefits of reusing materials
- **WH may be replaced by Zero Waste Hierarchy.** Zero Waste Europe believes a new hierarchy is needed to change the mindset from waste management to resource management.
- Need to show optimal resource use can be seen as part of effort to establish a true circular economy where there is no waste and thus not exploiting new resources or disposing of materials.
- Adherence to UN Sustainable Development Goals - this means that the management of waste will not only have to adhere to a hierarchy that reflects the environmental impact, but which also responds to socioeconomic factors.

Past RD&D projects on Waste Hierarchy

- Many non-radiological case studies – but fewer radwaste examples such as:
 - NEA review of ‘Recycling and Reuse of Materials Arising from the Decommissioning of Nuclear Facilities’,
 - Cyclife Groupe EDF, operations in France , Sweden and UK
 - The Urenco Metal Recycling (UMR) facility at Urenco’s Capenhurst site in the UK
 - The Sizewell C Project, UK - Spent Fuel and Radioactive Waste Management strategy
- Non radiological:
 - Zhang, C. et al., 2022. An overview of the waste hierarchy framework for analyzing the circularity in construction and demolition waste management in Europe. *Science of The Total Environment*, Volume 803, p. 149892.
 - Pires, A. & Martinho, G., 2019. Waste hierarchy index for circular economy in waste management. *Waste Management*, Volume 95, pp. 298-305.
 - Aboagye, E., Chea, J. & Yenkie, K., 2021. Systems level roadmap for solvent recovery and reuse in industries.. *iScience.*, 24(10):. 103114.

Uncertainties

- Reported Domestic and international waste hierarchy practices are evolving with growing need to demonstrate sustainability. Therefore:
 - Increasing need to show that waste generation is being avoided.
 - Environmental legislation will only become more stringent over time - Methods for handling and processing materials will change.
 - This could affect not only what is considered waste but also waste categories and drive waste producers towards more rigorous segregation of materials.
- As demonstration of sustainability aligns more with philosophy of zero waste, then:
 - recycle and reuse may be viewed as less acceptable,
 - focus shifts solely to waste prevention - even less socio-economic favourable (not all communities will have the same view of what may be the best holistic solution).
- Changing public opinion on what is waste v ever tighter controls for minimising dose to workers and public along with avoidance of environmental discharges that challenge the processing of waste.

Guidance, training and communities of practice

Guidance

- Guidelines for National Waste Management Strategies, produced by the United Nations Institute for Training and Research (UNITAR) as part of the United Nations Environmental Programme 2013, (https://cwm.unitar.org/national-profiles/publications/cw/wm/UNEP_UNITAR_NWMS_English.pdf)
- OECD 'Guidance Manual on Environmentally Sound Management of Waste',
- IAEA offers a range of guidance covering all aspects of radioactive waste management

Training

- IAEA offers a variety of e-learning courses on waste management aspects, that can be accessed through their Open Learning Management System (<https://elearning.iaea.org/m2/>)
- EU Summer School on Nuclear Decommissioning & Waste Management Summer School on Nuclear Decommissioning & Waste Management. https://joint-research-centre.ec.europa.eu/tools-and-laboratories/training-programmes/summer-school-nuclear-decommissioning-waste-management-elinder-course-g5_en
- Chartered Institution of Waste Management (CIWM) in the UK provides training on all aspects of waste management, but this primarily focused on non-radiological wastes.

Active communities of practice and networks

- NEA Radioactive Waste Management Committee (RWMC) – provides a neutral forum where policymakers, regulators and implementing organisations can discuss issues of common interest, develop best practices and feasible solutions that meet the diverse needs of its participants.
- The ERDO Association is specifically focused on radioactive waste (<https://www.erdo.org/>).

Key references and future reading

- EU, 2008. Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on Waste and repealing certain Directives, 2008. *Official Journal of the European Union*, 19 November.
- EU, 2011. Directive 2011/65/EU of the Parliament and of the Council of 8 June 2011 on the Restriction of the use of Certain Hazardous Substances in Electrical and Electronic Equipment. *Official Journal of the European Union*, 8 June.
- IAEA, 1995. *Principles of Radioactive Waste Management Safety Fundamentals*, IAEA Safety Series No. 111-F,, Vienna: International Atomic Energy Agency .
- IAEA, 2022. *IAEA Nuclear Energy Series No. NW T 1.14 (Rev. 1), 'Status and Trends in Spent Fuel and Radioactive Waste Management'*, Vienna: International Atomic Energy Agency.
- NDA, 2020. *Radioactive Waste Strategy September 2019*. (<https://www.gov.uk/government/consultations/nda-radioactive-waste-management-strategy/outcome/radioactive-waste-strategy-september-2019>).
- NEA, 2017. *Recycling and Reuse of Materials Arising from the Decommissioning of Nuclear Facilities*, NEA No.7310, Paris: OECD.
- OECD, 2007. *Guidance Manual for the Implementation of the OECD Recommendation C(2004)100 on Environmentally Sound Management of Waste*, Paris: OECD Publications.
- OECD-NEA, 2004. *The Regulatory Control of Radioactive Waste Management - Overview of 15 NEA Member Countries*, NEA No.3597, Paris: OECD Publications.

Questions

1. What is the Waste Hierarchy?
 - A list of waste categories.
 - A stepwise approach to achieving waste minimisation.
 - A sequence in which waste should be generated
2. Which of the following is not in the Waste Hierarchy?
 - Disposal
 - Minimisation
 - Regeneration
 - Prevention
3. When should the Waste Hierarchy be considered?
 - During the planning phase of a project.
 - When the Regulator asks you about it.
 - At the end of a project.
 - At all stages i.e. throughout the full lifecycle of the project.

Questions contd.

4. How can you show that the Waste Hierarchy is being applied?
 - Documentation of the radioactive material processed, conditions used and where it has been transferred to,
 - Accurate characterisation and classification of materials recovered for reuse,
 - Accurate markings and labelling imposed on wasteforms and packages,
 - Verifying the recovered materials are safe for use; i.e. Recovered materials comply with specifications for reuse, wasteforms/packages meet WAC for storage or disposal.
 - All the above

5. Which of the following are challenges or uncertainties for the Waste Hierarchy?
 - Need to show optimal resource use and move to zero waste.
 - Need to balance environmental impact with socioeconomic issues.
 - Radioactive waste is not the same as ordinary wastes.
 - Definition of waste and what can be done with materials will change in the future.