2.1.4 WASTE HIERARCHY; DOMAIN INSIGHT

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OVERVIEW

The objective of radioactive waste management is to control and account for radioactive waste to protect human health and the environment now, but also to make sure we do not leave unnecessary burdens for future generations. The preferred way to do this, where reasonably practicable, is to concentrate and contain the waste and to isolate it from the environment. This allows any releases to the environment to be restricted and subject to regulatory control. Radioactive waste is often defined as material that is either radioactive itself or is contaminated by radioactivity, for which no further use is envisaged. However, from a sustainability perspective, before material can be considered as of 'no further use' it needs to be shown that all opportunities have been taken to extract benefit from the material either in its original or alternative use.

The Waste Hierarchy (WH) is a stepwise approach to achieving waste minimisation to promote sustainability that considers the life cycles of both the processes that create waste and the waste that is produced from them. The WH is shown schematically in Figure 1 below:

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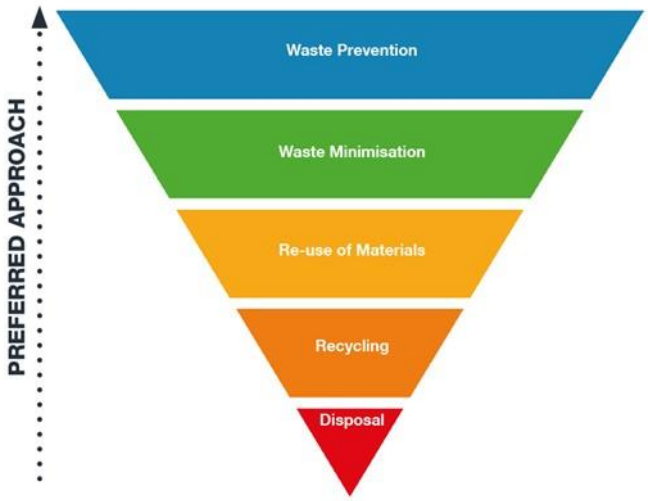

Figure 1. Schematic representation of the Waste Hierarchy concept [NDA, 2020]

This idea was first introduced in 1975 in a European Economic Community, Council Directive for non-radiological waste [EU, 1975], but the term Waste Hierarchy was not used. Rather it promoted the prevention or reduction of waste production along with the recovery of waste by means of recycling, re-use or reclamation or any other process with a view to extracting secondary raw materials, or the use of waste as a source of energy.

It promotes managing waste in the following order of priority:

- **Prevention**: Prevent or reduce at source, as far as possible, the creation of waste, to secure the conservation of nature and resources.
- **Minimisation**: Reduce volume and/or radioactivity content of waste generated. This encompasses using techniques such as: segregation, decontamination and decay storage to allow reclassification of waste.
- **Reuse**: Where waste cannot be prevented, waste materials or products should, where appropriate, be reused directly or refurbished and then reused.
- **Recycling**: Where appropriate, waste materials should be recycled or processed into a form that allows them to be reclaimed as a secondary raw material.
- **Other recovery**: Waste material is utilized to replace other materials that would otherwise have been used to fulfil a particular function in the plant or in the wider economy, examples would be recovery of solvents, acid/base regeneration, recovery of materials of value or energy recovery.
- **Disposal**: Only if waste cannot be prevented, reused, recycled, or recovered should it be disposed of into the environment, and this should only be undertaken in a controlled, safe and authorised manner.

KEYWORDS

predisposal, waste hierarchy, categorisation, waste processing, storage, disposal, safety, radiation protection

KEY ACRONYMS

ALARP – As Low As Reasonably Practicable
CoC – Certificate of Compliance
DGR – deep geological repository
DEFRA – Department of Environment, Food and Rural Affairs
EFTA - European Free Trade Association
EWH - Environmental Waste Hierarchy
EPA - Environmental Protection Agency
EU – European Union
GBS – goals breakdown structure
HLW - High Level Waste
IAEA – International Atomic Energy Agency
ILW- Intermediate Level Waste
LLW - Low Level Waste
LSA - Lower Specific Activity
MS – Member State
NPP – Nuclear Power Plant
NORM - Naturally Occurring Radiological Material
OECD - Organisation for Economic Co-operation and Development
PSWP - Product & Secondary Waste Plan
PIP - Project Implementation Plan (or Programme)
POCO - Post Operational Clean-Out
RCRA - Resource Conservation and Recovery Act
RD&D – Research, Development, and Demonstration
RoHS - Restriction of Hazardous Substances
RW – radioactive waste
RWM – radioactive waste management
SDG - Sustainable Development Goals
VLLW - Very Low Level Waste

1 TYPICAL OVERALL GOALS AND ACTIVITIES IN THE DOMAIN OF WASTE HIERARCHY

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	
2.1.4 Evaluate options to apply waste hierarchy to minimise waste volumes at higher impact inventory disposal levels (Waste Hierarchy)	
Domain Activities	
Phase 1: Planning and Programme Initiation	Consider the full 'life cycle' of the processes that may produce waste; establish the anticipated types, quantities and locations of potential waste arisings and existing stored waste. Look at the other EURAD Roadmap Domains of [CFR, 2023] Determine what treatment or conditioning can be applied to the waste and identify potential opportunities to prevent, minimise, reuse, or recycle the waste material or recover other value from it before committing the minimal amount of waste for 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.
Phase 2: Programme Implementation	Identify facility requirements – can these be met through use of existing facilities/plant (modified if necessary) 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 products including arrangements for transferring products 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 them as necessary. Implement POCO/Decommissioning strategy/plans.

2 INTERNATIONAL LEGISLATION

Radioactive waste management

The regulatory demands and legislation associated with radioactive waste management are focused on controlling the storage, handling, and treatment of radioactive waste to ensure that human health and the environment are protected now and in the future. Responsibility for waste management is with the original waste producer or other waste owner who must ensure that appropriate waste treatment is carried out (this may be themselves or by appropriate other organisation) in accordance with Articles 4 and 13 of the European Directive 2008/98/EC on Waste (the Waste Framework Directive) [EU, 2008]. Whilst the primary concern of waste regulations has been and remains the management of safety risks, the trend in recent legislation is increasingly focused on reducing the environmental impact of waste and the development of sustainable waste management strategies. Additionally, by recycling of materials, natural resources can be saved and the amounts of radioactive waste that require disposal can be reduced, which in the end could lead to an optimised use of available disposal options.

In the USA, similar evolutions in waste management were occurring with the establishment of the Resource Conservation and Recovery Act (RCRA) in 1976 [CFR, 2023] that gave control of hazardous waste to the Environmental Protection Agency (EPA) from ‘cradle to grave’, including its generation, transportation, treatment, storage, and disposal. Although the focus was more pollution prevention than waste reduction. However, just as in Europe, the focus has evolved to encompass sustainability with the initial focus shifting to include the 3 Rs, i.e., Reduce, Re-use, Recycle.

Waste hierarchy

The waste hierarchy is a stepwise approach to achieving waste minimisation to promote sustainability that considers the lifecycles of both the processes that create waste and the waste that is produced from them, this idea was first introduced in the European Union's Waste Framework Directive (1975/442/EEC). Subsequently, the waste hierarchy approach has been fully embraced, such that European Directive 2008/98/EC [EU, 2008] encourages the adoption of options for managing waste in the order of priority **shown in** Figure 1**.**

Most recently the requirements for waste prevention have been strengthened in EU Directive 2018//851 [EU, 2018].

These principles have been adopted across the European Union where all countries have developed a waste prevention plans (profiles), the latest of which were published in May 2023 (European Environment Agency, 2023). Similarly in associated countries such as the UK, where the legal requirement to apply the waste hierarchy was enshrined in law through the Waste (England and Wales) Regulations 2011 [DEFRA, 2011]. The most recent requirements and guidance is summarised in the Waste Management Plan for England, January 2021 [DEFRA, 2021],

The regulators consider that, so far as is reasonably practicable, they should be applied during the planning, design, construction, manufacture, commissioning, operational and decommissioning stages of a facility.

As stated above, the primary legislative driver for application of the waste hierarchy has been the European Directive 2008/98/EC on Waste [EU, 2018] that Directive led to complementary/complying legislation in other countries associated with the EU.

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 [UN, 2016] named “Responsible consumption and production”: “by 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse”.

It should be noted that the above legislation covers all waste including hazardous wastes, so it encompasses radioactive waste without being specifically focused on the radiological aspect and impacts.

An underlying feature of all the legislation in all jurisdictions is that the waste regulations apply to all phases of operations involving radioactive materials from initial design and licensing to post-operation, decommissioning and final disposal. From the initial conception, the design development needs to consider waste minimisation and from the radiological perspective strive to ensure that waste where generated is kept to the lowest classification possible and encompass the use of VLLW in addition to LLW, ILW and HLW although classifications can vary among countries. This is discussed more fully in the Inventory Domain Insight (2.1.1). It is common for plans and funding for eventual post-operation close-out and decommissioning to be a requirement before new plants can be permitted for construction and operation.

It is worth remembering that arisings of radiological wastes are much broader than just those associated with nuclear power generation and subsequent spent fuel processing. Wastes arise from medical isotope and source production as well as from processing Naturally Occurring Radiological Material (NORM), e.g., from phosphate mineral processing or coal burning. Hence all industrial processes must

be aware of the potential for NORM to be present or Lower Specific Activity (LSA) materials to be generated and the subtleties of handling these materials compared with more highly radioactive materials need to be considered.

An important issue to consider is that reuse and recycling initiatives are governed by case-specific release criteria, or licences, which frequently vary from country to country or project to project. Consequently, the ability to direct material for other uses or even to ship material between countries, and even to other facilities within the same country, is found to be extremely difficult .These criteria are often referred to as 'clearance levels' [IAEA, 1996], which can be defined as the levels that have to be met to allow *'removal of radioactive materials or radioactive objects within authorised practices from any further regulatory control by the regulatory body'* [Nuclear Energy Agency, 2017].

Whilst EU guidelines exist for what the clearance criteria maybe they are not mandatory and are only advisory aiming to ensure a harmonised approach between EU member states within the European Community. The application of clearance levels by competent authorities is not prescribed by then relevant Council Directive 2013/59/Euratom [EU, 2013]. Moreover , the Directive does not prescribe harmonisation of clearance levels across the EU since it is recognised that there are other factors in addition to radiological protection that may also need to be considered.

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)**.**

3 GENERIC SAFETY ISSUES FOR WASTE HIERARCHY

This section describes the safety precautions associated with radioactive material waste hierarchy 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 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 waste and what treatment or conditioning can be applied to both newly generated or existing waste stocks. This allows an inventory to be established of anticipated types, quantities and locations of potential waste arisings and existing stored waste. For further information, please see the other EURAD Roadmap Domain Insights of National Inventory (1.4), Inventory (2.1.1) Key requirements include:

- Identify potential 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 and stakeholder requirements, undertake environmental impact assessment; assess whether potential segregation, treatment or

conditioning can be undertaken safely (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 plans must reflect good practice and utilise the waste hierarchy philosophy.

3.2 Programme Implementation

In keeping with the implementation of any industrial process, radioactive waste management will involve the following steps:

- 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 for segregating and storing different categories of waste, installation of decontamination capabilities and new treatment processes to modify the waste or separate out components for reuse/recycle.
- Can 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.

Getting closer towards actual operation of facilities and handling of radioactive waste streams, it is critical to understand the waste handling requirements and crucially how the waste material may change during each handling or treatment operation. Prior to actual movement of radioactive materials, it is necessary to make a detailed safety and quality plans and ensure all aspects meet the 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. This will of course involve confirmation of its chemical composition and physical characteristics but will also involve radiation measurements to ensure that it can be handled in downstream operations, especially if those processes are non-nuclear. Potentially, decay storage may have to be utilised in order to allow short lived radioactivity to decline so that the material

meets the Waste Acceptance Criteria. An analysis of possible safety risks and scenarios should be documented, including consequence assessments for hypothetical accident cases.
To facilitate the above consideration should be given to NEA report 7310 [Nuclear Energy Agency, 2017], since it provides a good summary of clearance practices in several countries, including case studies detailing recycling and reuse of materials.

During the implementation phase, Waste Hierarchy issues closely link to the other EURAD Roadmap Domain Insight on Characterisation (2.2.1), Treatment & Processing (2.2.2) and of Storage (2.2.4) which includes issues on packaging.

3.3 Programme Operation and Closure

During operation of (pre-disposal) waste management facilities there is a continuous process of reviewing operational performance against the PSWP and application of the waste hierarchy. It is important to continuously determine if waste minimisation and material recovery objectives are being met. The facility operators 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 plant, regulatory oversight requires that evidence is retained of the performance of the plant and any modifications made. In regard to 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:
    - Recovered materials comply with specifications for reuse,
    - wasteforms/packages meet WAC for interim stores or disposal sites.

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.

Indeed, during the decommissioning itself the plant/facility structural materials and equipment dismantled should continue to support the WH. Throughout the implementation 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.

During the long-term operation phase, Waste Hierarchy issues closely link to the other EURAD Roadmap Domain of Quality & Management Systems (2.3.1), Optimisation (2.3.2) and Secondary Waste Management (2.3.3).

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

The WH is an approach or philosophy that was developed for the management of general waste and does encompass hazardous wastes but was not developed specifically for radioactive waste.

The approach has been primarily developed within the European Union and is now enshrined within the laws and regulations of EU countries, and the rules are also followed by affiliates such as members of the European Free Trade Association (EFTA), e.g., Norway, Switzerland, and the UK which still retains the legislation despite now being outside of the EU.

Although derived from a single set of EU directives, the regulations have to be implemented at a national level and this does lead to some inconsistency within and across borders. There have been a variety of academic studies examining the application of the waste hierarchy in the EU, [Egüez, 2021]. Egüez found that countries treat waste based on the relative costs of different waste treatment options, population density, heating demand, and electricity prices in the waste treatment mix and the stringency with which environmental regulation was enforced. He noted that compliance with the Environmental Waste Hierarchy (EWH) has increased over time.

The utilisation of the WH has become well established in the general and hazardous waste industries with many companies offering services at a national and international level. Much of this activity is driven by initiatives promoting recycling in various sectors, for example:

- Waste Electrical and Electronic Equipment (WEEE) directive [EU, 2012]
- Restriction of Hazardous Substances (RoHS) Directive [EU, 2011]
- European strategy for recycling plastic materials [EU, 2018]

Additionally, there are increasing commercial/economic drivers to reduce the use of materials and recycle/reuse materials as much as possible especially those that are deemed ‘critical’ due to their scarcity or difficulties in supply examples being the platinum group metals and some of the rare earth elements [European Commission, May 2014].

There are numerous companies that offer waste management services many of these are members of associations such as:

- The Waste Facilities Audit Association (WFAA) which comprises some forty UK, European and International companies.
- Chartered Institution of Waste Management (CIWM)
- International Solid Waste Association (ISWA)

The ERDO Association is specifically focused on radioactive waste (https://www.erdo.org/). It was founded to allow organizations involved in radioactive waste management to work more closely together on the common challenges in managing radioactive waste safely by sharing knowledge, implementing joint projects and promoting multinational waste management solutions internationally.

A key issue is the extent to which the WH promotes a circular economy [Pires & Martnho, 2019] – it is certainly geared to reducing waste and extracting value from it but that is not necessarily the same as supporting a circular economy. This is illustrated by the discussion over waste prevention which in WH is a top priority, but in a circular economy waste can be produced if it is subsequently fully reprocessed to allow material to be returned for further use – especially if the process is 100% efficient. However, in such a case it might be argued it is never waste. Another issue comes with incineration of waste to generate heat/electricity a process accepted in the WH, but which is viewed as consumption of material in the circular economy.

Both approaches support waste minimisation, but the circular economy philosophy would be viewed as the more sustainable approach.

5 MATURITY OF KNOWLEDGE AND TECHNOLOGY

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

Radioactive waste management is a mature aspect of the overall nuclear industry as well as supporting the use of radio isotopic materials in medical and industrial applications. Principles of good practice can be found in publications from international bodies such as the IAEA [IAEA, 1995] or the NEA [OECD-NEA, 2004] and these help waste holders comply the regulatory requirements that were discussed in Section 2.

Advances in waste hierarchy issues

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:

- the 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 downgraded to lower radiological category and or permitted for free release.

Optimisation challenge and innovations

The implementation of total lifetime assessments using tools such as Life Cycle Analysis (LCA) [ISO, 2006] has heightened awareness of the environmental impact of waste generation and the benefits of reusing materials. This may also be manifested in WH being replaced by Zero Waste Hierarchy. Zero Waste Europe believes a new hierarchy is needed to change the mindset from waste management to resource management [Zero Waste Europe, 2019]. This optimal resource use approach can be viewed as part of efforts to establish a true circular economy

where there is no waste. Such approaches places greater emphasis on keeping resources in use and not exploiting new resources or disposing of materials.

In addition to meeting the environmental challenges the application of WH or its replacements will have to be applied such that sustainability objectives are being met. In simple terms sustainability can be viewed as being achieved when the needs of the present are met without compromising the ability of future generations to meet theirs. Sustainable development is based on the three pillars (or principles) of environmental, social, and economic sustainability as described in the so called Brundtland Report [World Commission on Environment and Development, 1987] and which underlay the UN's SDG [UN, 2016]. 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.

6 PAST RD&D PROJECTS ON WASTE HIERARCHY

There are numerous examples of application of the WH to non-radiological wastes, but far fewer examples of its application as part of radioactive waste management of which the following are a selection, and by no means a comprehensive list:

- NEA review of 'Recycling and Reuse of Materials Arising from the Decommissioning of Nuclear Facilities', [NEA, 2017]. This highlights experience from operations to recover metals, concrete and recover for reuse large components.
- Use of WH to review construction and demolition waste management practice in Europe [Zhang, et al., 2022]
- A WH index has been proposed as an indicator of how effectively waste is being managed [Pires & Martinho, 2019]
- The Urenco Metal Recycling (UMR) facility at Urenco's Capenhurst site in the UK is a project being progressed by Urenco Nuclear Stewardship to implement a treatment facility for radioactive metal waste [Hennelly & Tarry, 2022]. Whilst the UMR facility will have a number of benefits for UK, notably contributing to carbon emissions reductions and thus helping to meet Net Zero targets; it also represents an excellent example of the benefit of implementing the WH.
- An excellent overview of solvent recovery techniques and strategies is provided by [Aboagye, et al., 2021], this also consider how changes in environmental legistration and moves to use WH etc influence approaches taken by industries.
- The Sizewell C Project, UK - Spent Fuel and Radioactive Waste Management strategy. https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010012/EN010012-001812-SZC_Bk6_ES_V2_Ch7_Spent_Fuel_and_Radioactive_Waste_Management.pdf

7 UNCERTAINTIES

Domestic and international waste hierarchy practices are evolving with growing need to demonstrate sustainability. Therefore, there will be an increasing need to show that waste generation is being avoided. Moreover, since it is reasonable to assume that environmental legislation will only become more stringent over time methods for handling and processing materials will also have to change. Such tightening of the regulations and increasing need to avoid materials being disposed of as waste, could not only affect what is considered as a waste but also the waste category that material is assigned to and drive waste producers towards more rigorous segregation of materials.

It is also clear that changing attitudes towards how sustainability is demonstrated and the philosophy of zero waste becomes the core attribute to be achieved then recycle and reuse may be viewed as less acceptable, and all the focus may shift to waste prevention even though that may not be the most socio-economic favourable approach in all cases, i.e. not all communities will have the same view of what may be the best holistic solution.

Future concerns can include public opinion on what is waste versus ever tighter controls for minimising dose to workers and the public along with avoidance of environmental discharges that challenge the processing of waste.

8 GUIDANCE, TRAINING AND COMMUNITIES OF PRACTICE

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

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Guidance
• An excellent overview of the topic can be found in 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 • The Organisation for Economic Co-operation and Development (OECD) issued a 'Guidance Manual on Environmentally Sound Management of Waste' in 2007, which while not recommending use of the waste hierarchy it does promote waste minimisation both in terms of its quantities and risks. Moreover, it recommends associated ideas of considering the full life cycle and promoting reuse and recycle of materials to achieve objectives of sustainable use of natural resources and protection of human health and the environment [OECD, 2007]. • For a more nuclear waste focused view, the International Atomic Energy Agency (IAEA) offers a range of guidance covering all aspects of radioactive waste management. Examples include: ○ Classification of radioactive waste [IAEA, 2009] ○ Storage of radioactive waste [IAEA, 2006] ○ Status and trends in Spent Fuel (SF) and Radioactive Waste Management (RWM) [IAEA, 2022] What is interesting is that the IAEA guidance does not address use of the waste hierarchy directly, instead the focus is primarily on waste minimisation (encompassing prevention and reduction). This is clearly stated in the IAEA guidance on the 'Predisposal Management of Radioactive Waste' [IAEA, 2009]. •
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 competences that are needed in applying the waste hierarchy to radioactive waste management include radiation safety, waste chemistry, material handling, waste treatment, logistics, radiological measurements and monitoring, data handling and preservation, risk management, scenario preparation, communication (stakeholder engagement), programme management.

9 ADDITIONAL REFERENCES AND FUTURE READING

Copies of all EU regulations can be found through this link: https://eur-lex.europa.eu/search.html?scope=EURLEX&text=waste+hierarchy&lang=en&type=quick&qid=1645781662066

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