IAEA 60 Years
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Advances in conditioning of low- and intermediate-level nuclear waste

M. Ojovan*, R. Robbins*, M. Garamszeghy**
*** IAEA, Vienna; ** NWMO, Canada**

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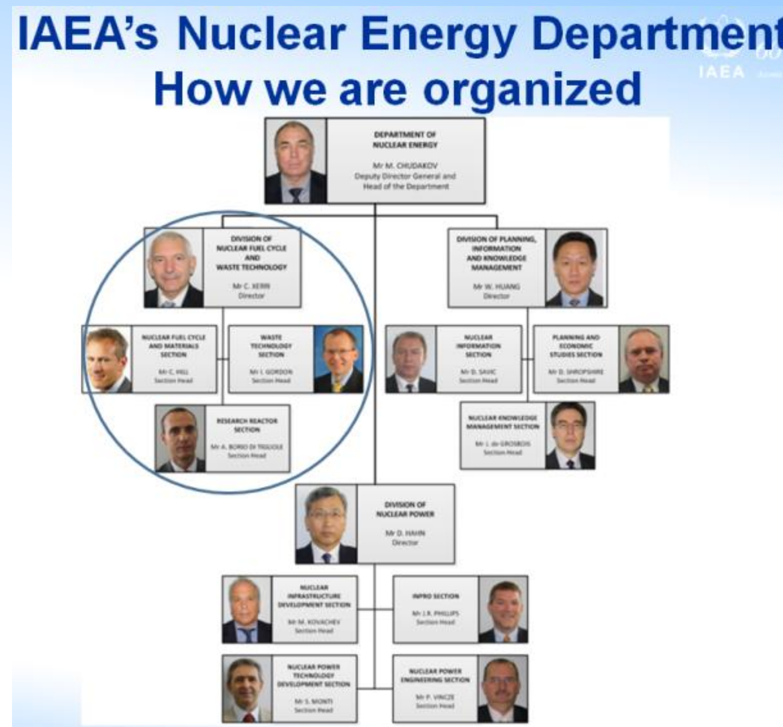
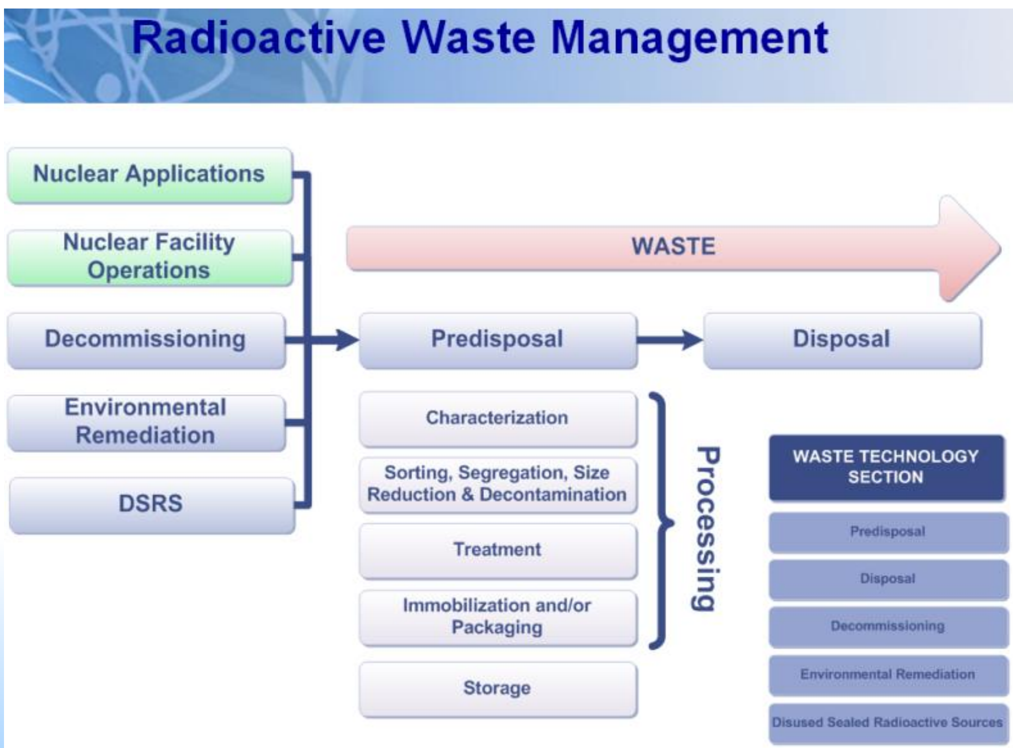
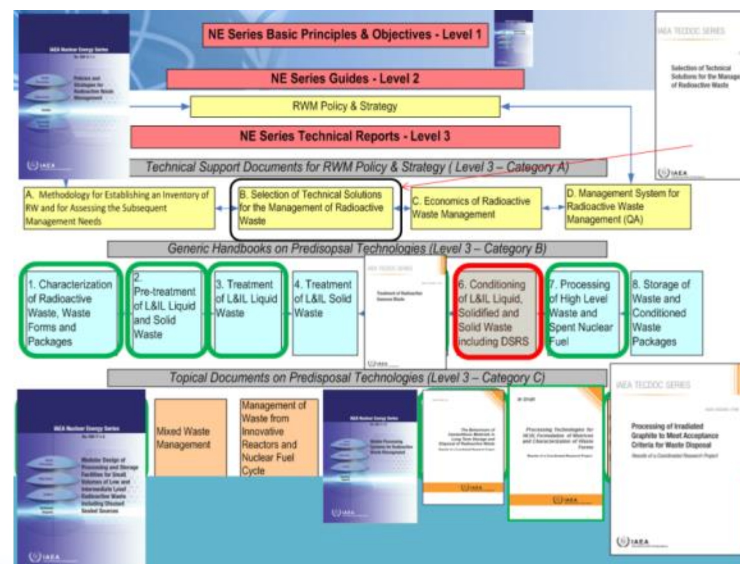
Contents

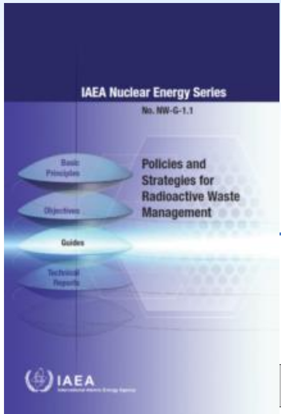
- About the IAEA & Handbook(s)
- Background to Conditioning (handbook structure and contents)
- IAEA Support activities
- Conclusions

About the IAEA & HB's









NE Series Basic Principles & Objectives - Level 1

NE Series Guides - Level 2

RWM Policy & Strategy

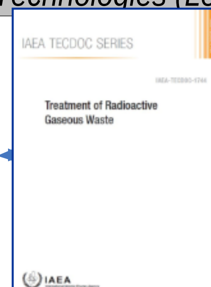
NE Series Technical Reports - Level 3

Technical Support Documents for RWM Policy & Strategy (Level 3 – Category A)

- A. Methodology for Establishing an Inventory of RW and for Assessing the Subsequent Management Needs
- B. Selection of Technical Solutions for the Management of Radioactive Waste
- C. Economics of Radioactive Waste Management
- D. Management System for Radioactive Waste Management (QA)

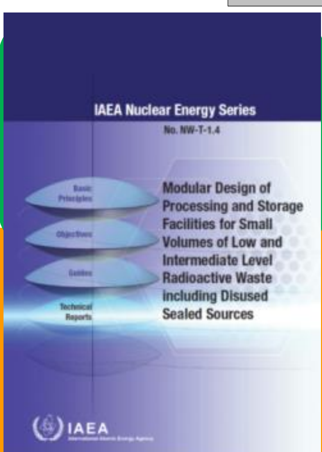
Generic Handbooks on Predisopsal Technologies (Level 3 – Category B)

1. Characterization of Radioactive Waste, Waste Forms and Packages
2. Pre-treatment of L&IL Liquid and Solid Waste
3. Treatment of L&IL Liquid Waste
4. Treatment of L&IL Solid Waste



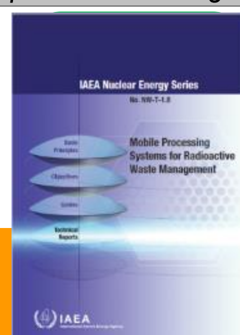
6. Conditioning of L&IL Liquid, Solidified and Solid Waste including DSRS
7. Processing of High Level Waste and Spent Nuclear Fuel
8. Storage of Waste and Conditioned Waste Packages

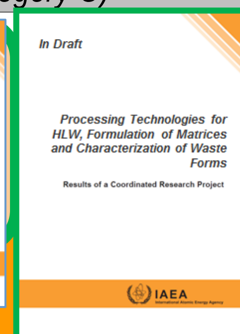
Topical Documents on Predisposal Technologies (Level 3 – Category C)

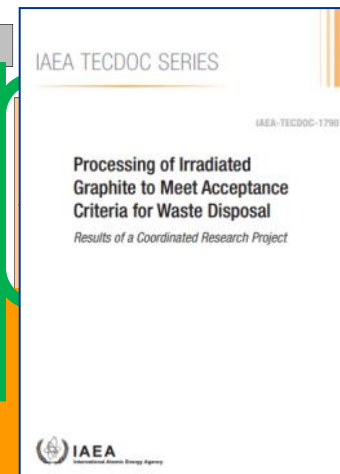


Mixed Waste Management

Management of Waste from Innovative Reactors and Nuclear Fuel Cycle





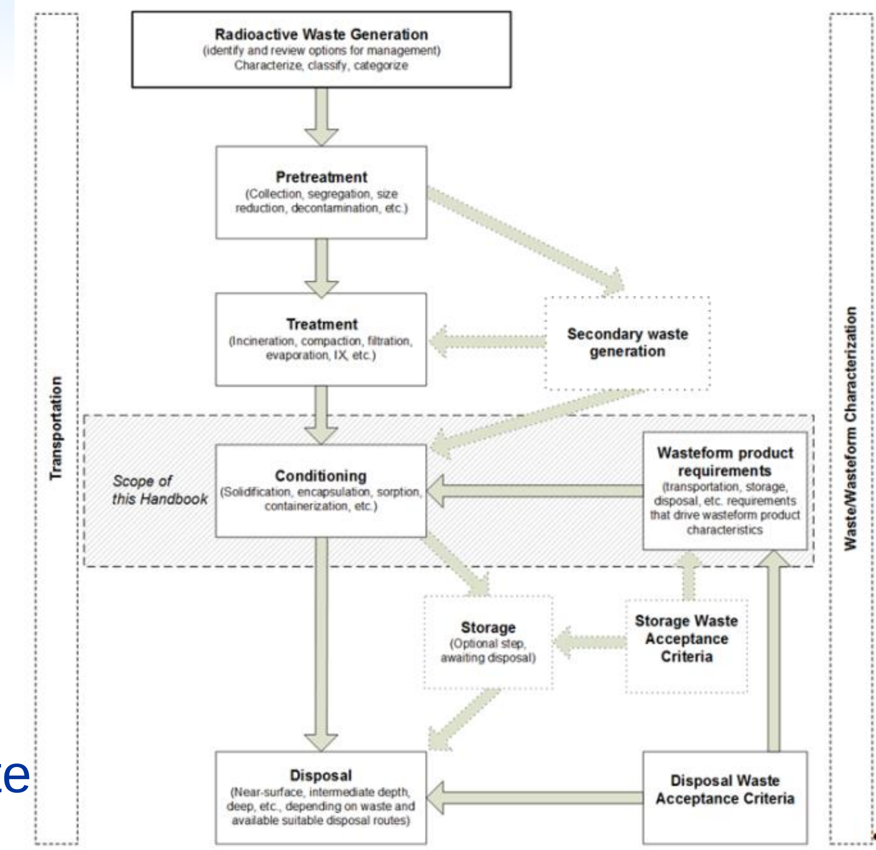


Background

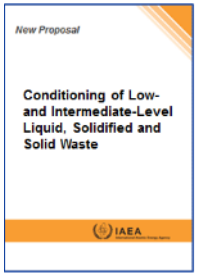
Conditioning may be performed for a variety of reasons including:

- standardization of practices and/or waste forms,
- technical requirements for waste stability in relation to a repository design or safety case,
- technical requirements related to waste transportation,
- societal preferences,
- regulatory preferences

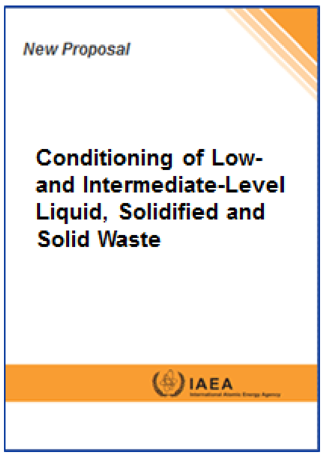
The reason for conditioning must be understood in order to select an appropriate method.



Different storage and repository designs and/or regulatory regimes may impose specific requirements.



The Conditioning Handbook is structured around five core technical chapters, followed by conclusions, and a series of appendices and case studies that contain greater detail.



Chapter 2: An overview of requirements and constraints for conditioning of radioactive wastes.
Chapter 3: Summaries of different types of wastes and the applicable conditioning technologies available for them.
Chapter 4: Various technology options.
Chapter 5: Typical process for selecting a suitable technology for a given circumstance.
Chapter 6: Wasteform testing requirements and methods.
Chapter 7: Conclusions and recommendations.
Appendix A: Glossary of relevant terms and abbreviations.
Appendix B: A brief descriptions of conditioning technologies.
Appendix C: Summaries of existing IAEA documents related to LILW conditioning.
Appendix D: Additional key documents related to LILW conditioning.
Appendix E: Examples of LILW Management Policies and Strategies from various member states.
Appendix F: Details of the waste classification systems used in various Member States.

APPENDIX C: Summary of Existing IAEA Documents

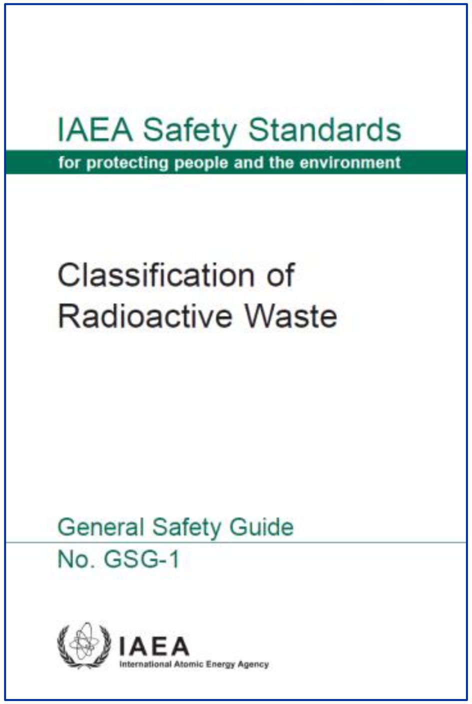
IAEA Publication	Scope	Comment
Bituminization of Radioactive Wastes, Technical Report Series 116 (1970)	Detailed technical report, with an underlying optimism that "bitumen is the universal matrix".	Early report, replaced by TRS-352.
Conditioning of Low- and Intermediate-Level Radioactive Wastes, Technical Report Series 222 (1983)	Classic cementation and bituminization processes are described, as well as polymer- and embedding processes (table describing the cementation and bituminization available at that time worldwide).	Early report, updated by TRS-350, TRS-360.
Treatment of Low- and Intermediate-Level Radioactive Solid Wastes, Technical Report Series 223 (1983)	The report describes the different options then available for treatment and conditioning of solid LILW.	Most of the techniques described are still in general use today. Some of the techniques described as being under development at that time, such as melting and plasma cutting are now in common usage. Early report, updated by TRS-360.
Treatment of Low- and Intermediate-Level Liquid Radioactive Wastes, Technical Report Series 236 (1984)	The report describes the different options then available for treatment and conditioning of liquid LILW.	Most of the techniques described are still in general use today. However, significant advances have been made since that time. Early report, updated by TRS-370.
Treatment of spent Ion-Exchange Resins for storage and disposal, Technical Report Series 254 (1985)	The report describes the different options then available for treatment and conditioning of IX resins.	Most of the techniques described are still in general use today. However, some advances have been made since that time. Early report, replaced by TRS-408.
Treatment of Alpha Bearing Waste, Technical Report Series 287 (1988)	The report describes the different options then available for treatment and conditioning of alpha-bearing wastes.	Most of the techniques described are still in general use today. However, significant advances have been made since that time. Early report, updated by TRS-326.
Immobilization of Low- and Intermediate-Level Radioactive Waste with Polymers, Technical Report Series 289 (1988)	The report describes the different options then available for immobilization of LILW in polymers.	Many of the techniques described are still in general use today. However, significant advances have been made since that time. Early report. The report has not been specifically updated. However, more recent information can be found in TECDOC-655, TECDOC-1504 and TRS-408.
Options for Treatment and Solidification of Organic Radioactive Wastes, Technical Report Series 294 (1989)	The report describes the different options then available for treatment and conditioning of organic radioactive wastes.	Most of the techniques described are still in general use today. However, significant advances have been made since that time. Early report, replaced by TRS-427.
Management of Abnormal Radioactive Wastes at Nuclear Power Plants, Technical Report Series 307 (1989)	The main topic of the report is management of waste generated as the result of an accident or similar abnormal event. It covers the full range from planning, pretreatment, treatment, conditioning and storage/disposal.	Most of the techniques described are still in general use today. However, significant advances have been made since that time. TRS 307 is currently being replaced by a newer report "Experience and Lessons Learned in Predisposal Management of Radioactive Waste in the Aftermath of Nuclear Accidents" (under development).
Conditioning of Alpha Bearing Wastes, Technical Report Series 326 (1991)	The objective of this report is to present state of the art information on assessments of the complex options available in the management of alpha bearing wastes from the reprocessing of spent fuels and MOX fuel fabrication.	Most of the techniques described are still in general use today. However, some advances have been made since that time. Report provides and update to TRS-287.
Chemical Precipitation Processes for the treatment of Aqueous Radioactive Waste, Technical Report Series 337 (1992)	The report describes the different options then available for chemical precipitation as a treatment option for liquid aqueous wastes. The precipitation wastes generally require further conditioning, as described in this current publication.	Many of the techniques described are still in general use today. However, significant advances have been made since that time. This report has not been updated.

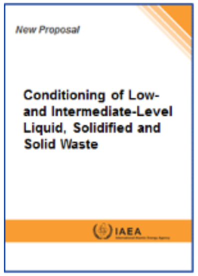
APPENDIX D: Summary of Additional Key Documents

Document Number	Title / Author(s) / Publisher	Publication Date	Comments
ISBN 978-0-08-099392-8	An Introduction to Nuclear Waste Immobilization, 2nd edition M.I. Ojovan and W.E. Lee (Editors) Elsevier Insights Series	2014	The book provides an overview of common radioactive waste immobilization methods, including cement, bitumen, glass and ceramics. It covers LLW, ILW and HLW. The descriptions are current and new developments are described.
ISBN 978-1-84569-626-9	Handbook of advanced radioactive waste conditioning technologies M.I. Ojovan (Editor) Woodhead Publishing Series in energy: Number 12	2011	The book provides an overview of common radioactive waste treatment and conditioning methods, including incineration, plasma arc treatment, vitrification, supercompaction, cementation and geopolymers. It covers LLW, ILW and HLW and includes extensive descriptions of existing processes and facilities, as well as related research activities. The descriptions are current and new developments are described.
ISBN 978-1-4614-3444-3	Cement-based materials for nuclear waste storage F. Bart, C. Cau-dit-Coumes, F. Frizon and S. Lorente (Editors) Springer Science+Business Media	2013	The book gathers 22 scientific contributions that have been selected from NUWCEM, the first international Symposium on cement-based Materials for Nuclear Wastes (Avignon, France, 2011). The book is divided in 4 parts: • Methods of production of cement-wasteforms • Physico-chemical processes occurring in cement-wasteforms at early age • Influence of external and internal factors on long term properties of cement-waste package and cement barriers • Emerging and alternative cementitious systems The report is current and describes new developments.
ISBN: 9781118512005	Cementitious materials for nuclear waste immobilization Rehab O. Abdel Rahman, (Editor), John Wiley & Sons, Ltd., Chichester, UK	2015	Approaches and current practices of use of cementitious materials for nuclear waste immobilization are summarized in this book, with a focus on the most important aspects of cements as nuclear wasteforms. The topics covered include an introductory background on nuclear waste management, description of Portland cements and cements with mineral and chemical admixtures, alternative cementitious binders, radioactive waste cementation and equipment used, wasteform durability requirements and testing, and performance assessment. Overall the book provides the reader with both a scientific and technological basis of using cementitious materials for immobilization of nuclear waste. The report is current.
ISBN 978-0-309-18733-6	Waste Forms Technology and Performance: Final Report Committee on Waste Forms Technology and Performance, National Research Council The National Academies Press	2011	The US Department of Energy's Office of Environmental Management (DOE-EM) is responsible for cleaning up radioactive waste and environmental contamination resulting from five decades of nuclear weapons production and testing. A major focus of this program involves the retrieval, processing, and immobilization of waste into stable, solid wasteforms for disposal. This report, which was requested by DOE-EM, examines requirements for wasteform technology and performance in the cleanup program. It is intended to provide information to DOE-EM to support improvements in methods for processing waste and selecting and fabricating wasteforms. The report is current.
AECL report # 146-508600-TD-001	Summary of International Practices for Radioactive Waste Conditioning and Treatment E. Janzen Atomic Energy of Canada Limited (internal report)	2013	The report summarizes global national strategies and practices for treatment and conditioning of RW (on-site, off-site and mobile installations) for 16 countries, covering the whole range of wastes (L, I and HLW), from production to disposal (or future disposal). The report includes a brief description of the techniques that are used for treatment and conditioning operations as well as a summary of existing facilities for these 16 countries. The report is current.
EUR 13252 EN	Immobilization of ion-exchange resins in cement C. G. Howard, C. B. Jolliffe, D. J. Lee Commission Of The European Communities	1991	The report describes techniques for immobilizing organic ion exchange resins of the polystyrene type in blended cement systems. The aim of the programme was to show that ion exchange resins used to remove activity from decontaminating agents can be successfully immobilized in cement. Various blends of Ordinary Portland Cement (OPC) and ground granulated Blast Furnace Slag (BFS) were used. The report presents the technical basis for an immobilization process system design along with expected wasteform characteristics. Although the report is somewhat dated, the basic methodologies described are still valid.

Waste types & classification

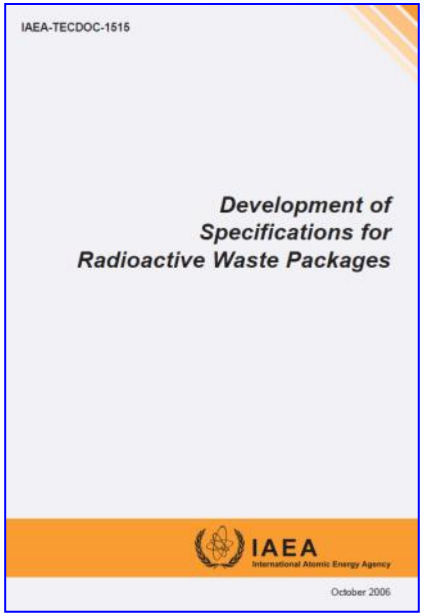
- Waste type & classification is an important consideration for choosing a conditioning method:
  - Solid, liquid, wet solid
  - Large, discrete items or fine particulate
  - Radionuclide content & concentration (LLW, ILW, HLW)
  - Chemical makeup (e.g. reactive metals, chemicals that disrupt a conditioning reaction)
- All have implications on process selection & design

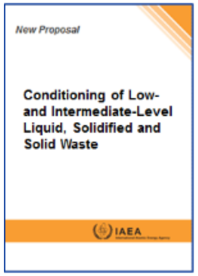




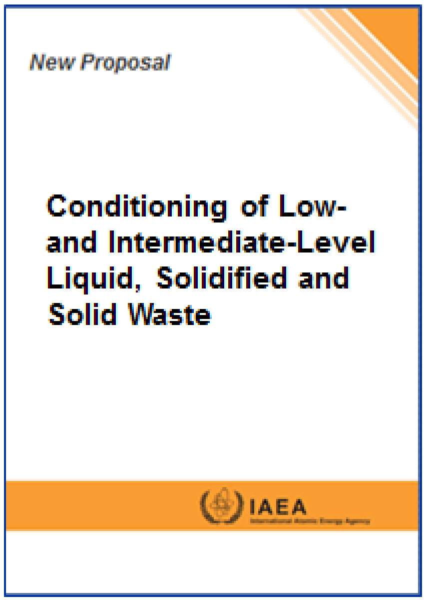
Waste package requirements

- Waste package includes container + waste form
- Final waste package must meet acceptance criteria for receiving storage or disposal facility:
  - Physical strength & durability
  - Radiation, thermal & chemical resistance
  - Radionuclide & chemical retention (e.g. leach resistance)
- Requirements will vary by country and/or facility
- Role & function of container vs waste form can be varied according to system design
  - Guided by economics & need for “defence in depth”





Conditioning basics


New Proposal

Conditioning of Low- and Intermediate-Level Liquid, Solidified and Solid Waste

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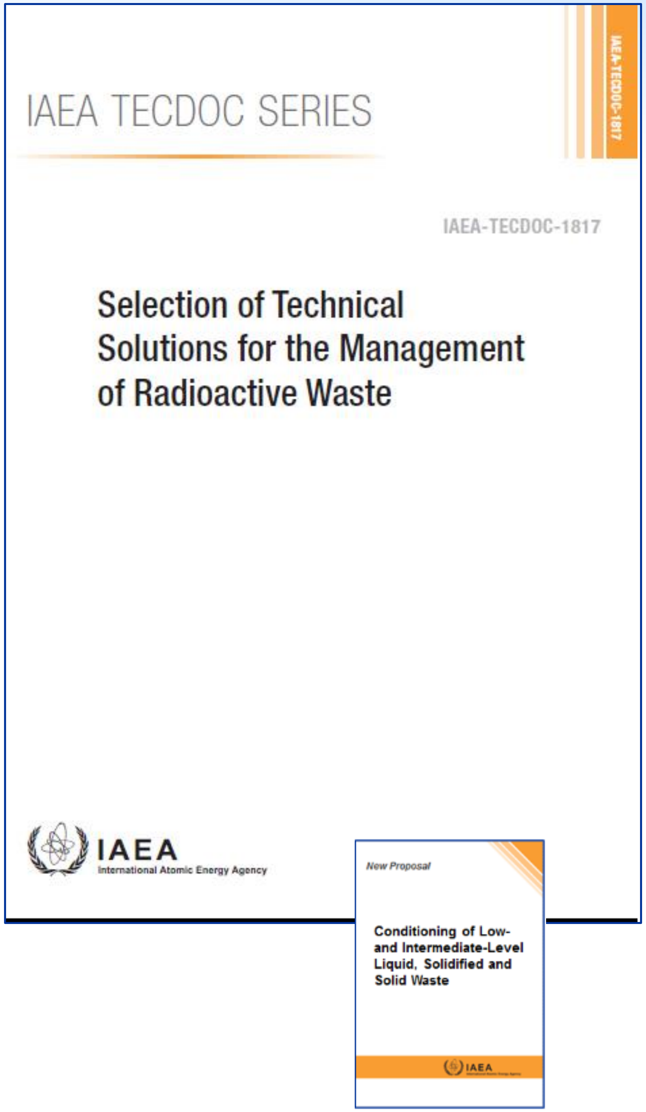
- Conditioning results in a waste package suitable for long-term storage or disposal
- Immobilization is the production of the waste form that goes into the container
- Immobilization can be homogeneous (e.g. solidification of a liquid) or heterogeneous (e.g. encapsulation of solid pieces)
- Many processes & matrices are available

Process selection

- Choosing the appropriate process depends on a number of factors:
  - Properties of original waste
  - Desired properties of waste form
  - Scale of operation
  - Economics
  - Resource availability
  - Non-technical factors (regulatory, social, etc)
- Usually, no single “right answer”



Waste	Form	Treatment	Conditioning		Disposal options
			Immobilization	**Packaging**	
VLLW Very Low-level waste	Solid	Decay Storage	Not normally used	None or simple packaging	Surface trench, Landfill, Near surface disposal
	Liquid Sludge	Decay Storage Evaporation, Radionuclide Removal Membrane methods, ion exchange	Cementation, Polymer Sorption	Industrial packaging	Surface trench, Landfill, Near surface disposal
LLW Low-level Waste	Solid	Sorting, Volume Reduction Compaction, Super-compaction, Incineration, Melting	Encapsulation, Grouting	Industrial packaging Metal or concrete containers, High-integrity Containers	Near-surface disposal
	Liquid & Sludge	Chemical treatment, Evaporation Radionuclide Removal Membrane methods, Ion exchange	Cementation, Bituminization, Polymer Sorption, Geopolymer Solidification, Vitrification	Metal or concrete containers, High-integrity Containers	Near-surface disposal
ILW Intermediate- Level Waste	Solid	Sorting, Volume Reduction Compaction, Super-compaction	Encapsulation, Grouting	Metal or concrete containers, High-integrity Containers	Intermediate depth disposal, Deep Geological disposal
	Liquid & Sludge	Chemical treatment, Evaporation Radionuclide Removal Membrane methods, Ion exchange	Cementation, Bituminization, Polymer Sorption, Geopolymer Solidification, Vitrification	Metal or concrete containers, High-integrity Containers	Intermediate depth disposal, Deep Geological disposal

Waste	Form	Treatment	Conditioning		Disposal options
			Immobilization	Packaging	
NORM / TENORM	Solid	Storage as potential resource or considered as waste	Not normally used	Not normally used	Near-surface storage
	Liquid and residues from liquid treatment	Chemical treatment, Evaporation Radionuclide Removal Membrane methods, Ion exchange	Cementation	Industrial packaging	Near-surface disposal
High Volume Wastes	Environmental	Radionuclide Removal	Encapsulation Grouting	Not normally used	Near-surface disposal
	D&D Waste	Radionuclide Removal	Encapsulation Grouting	Not normally used	Near-surface disposal
	Accidental Waste	Radionuclide Removal	Encapsulation Grouting	Not normally used	Near-surface disposal
Special Wastes	Disused sealed radioactive sources (DSRS)	Decay Storage	Encapsulation	Seal welded metal containers	Near-surface disposal, Borehole disposal
	Reactive Metal	Decay Storage	Encapsulation	Vented metal or concrete containers	Near-surface disposal
	Graphite	Decay Storage, incineration	Annealing	Metal or concrete containers	Near-surface disposal, Intermediate depth disposal, Deep Geological disposal
	Sodium Waste	Chemical treatment	Encapsulation	High-integrity Containers	Near-surface disposal
	Biological Waste	Decay Storage, incineration	Encapsulation Grouting	Metal or concrete containers	Near-surface disposal

Problematic wastes

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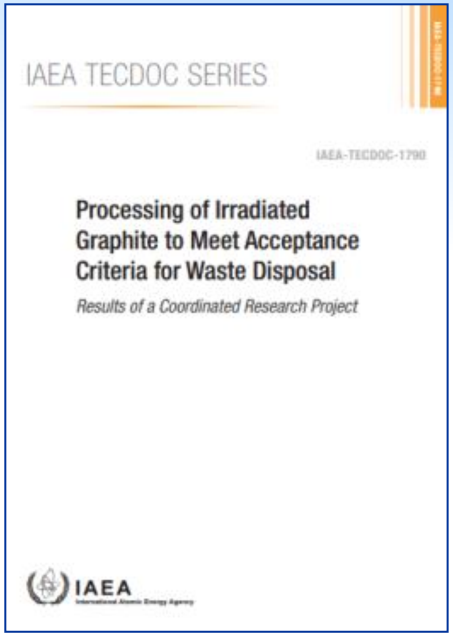
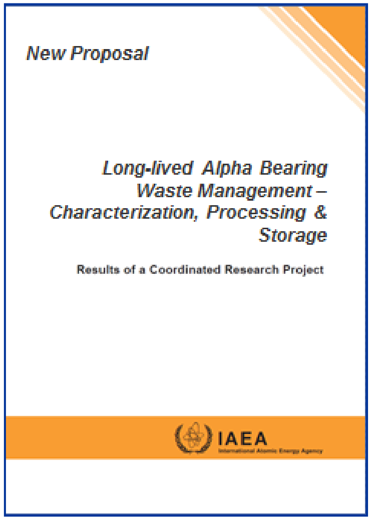
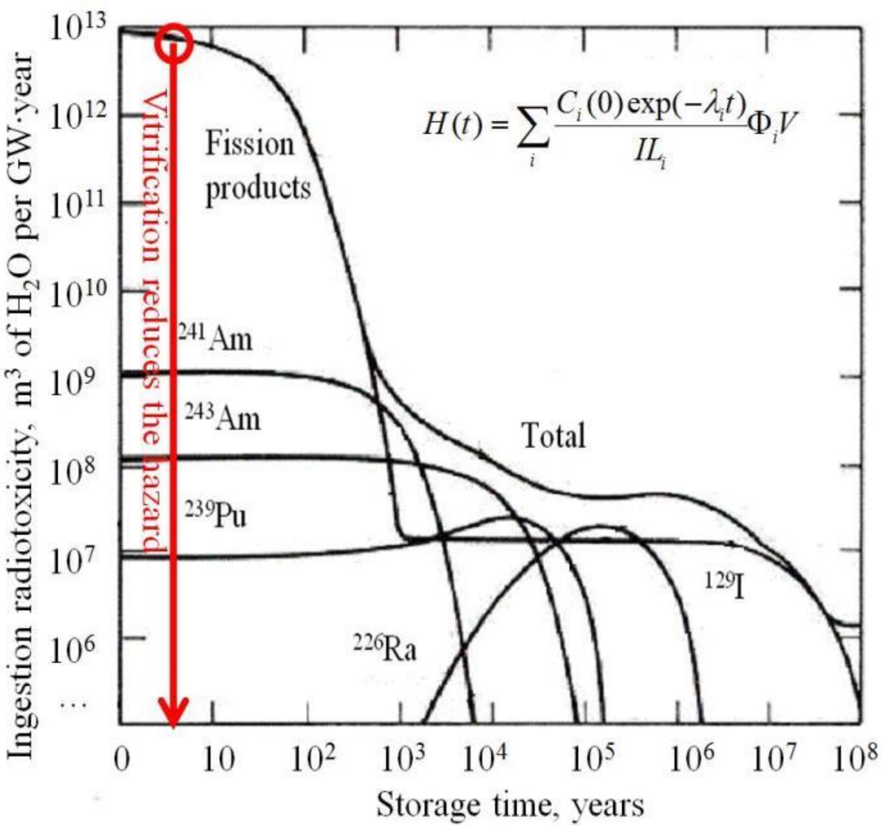
- “Problematic wastes” are those that are poorly compatible with standard conditioning methods, usually due to chemical interferences, physical properties, etc.
- Examples include:
  - Reactive metals (chemical reactions)
  - Heavy/toxic metals (poor retention)
  - Ion exchange resins (poor waste form due to swelling)
  - Graphite (Wigner energy)
  - Tritiated materials (poor retention & high mobility of tritium)
  - Organic liquids (low waste loading rate, poor retention)





Vitrification of LILW



R.A. Robbins, M.I. Ojovan. Vitreous Materials for Nuclear Waste Immobilisation and IAEA Support Activities. *Mat. Res. Soc. Symp. Proc.*, in press (2016).

Vitrification is the world-wide accepted technology for the immobilization of high level radioactive wastes.

- Glass can accommodate the range of constituents that are present in the waste into the glassy structure.
- The excellent durability of vitrified radioactive waste ensures a high degree of environmental protection.

Glass offers improved means of storing intermediate level nuclear waste

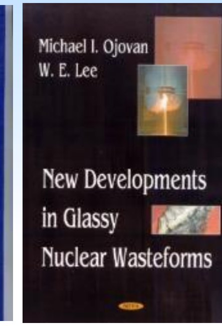
22 August 2012

A method of storing nuclear waste, normally used only for High Level Waste, could provide a safer, more efficient, and potentially cheaper method for Intermediate Level Waste.

Intermediate Level Waste (ILW) makes up more than three quarters of the volume of material destined for geological disposal in the UK. Currently the UK's preferred method is to encapsulate ILW in specially formulated cement. The waste is mixed with cement and sealed in steel drums, in preparation for disposal deep underground.

Two studies, published in the latest issues of ***The Journal of Nuclear Materials*** and ***European Journal of Glass Science and Technology*** this kind of waste into glass, a process called vitrification, could be a better met term storage, transport and eventual disposal.

http://www.dpaonthenet.net/article/52704/Glass-offers-improved-means-of-storing-intermediate-level-nuclear-waste.aspx



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The effect of pre-treatment parameters on the quality of glass-ceramic wasteforms for plutonium immobilisation, consolidated by hot isostatic pressing

Stephanie M. Thornber [a], Paul G. Heath [a], Gabriel P. Da Costa [a,b], Martin C. Stennett [a], Neil C. Hyatt [a,*]

[a] Immobilisation Science Laboratory, Department of Materials Science & Engineering, The University of Sheffield, Sir Robert Hadfield Building, Mappin Street, Sheffield S1 3JD, UK
[b] Department of Chemical Engineering & Petroleum Engineering, Universidade Federal Fluminense, Rua Passo da Patria 156, CEP 24210-240, Niteroi, RJ, Brazil

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ELSEVIER

The influence of glass composition on crystalline phase stability in glass-ceramic wasteforms

Ewan Maddrell [a,*], Stephanie Thornber [b], Neil C. Hyatt [b]

[a] National Nuclear Laboratory, Sellafield, Seascale, Cumbria CA20 1PG, UK
[b] Department of Materials Science and Engineering, The University of Sheffield, Mappin Street, Sheffield S1 3JD, UK

HIGHLIGHTS

- Crystalline phase formation shown to depend on glass matrix composition.
- Zirconolite forms as the sole crystalline phase only for most aluminous glasses.
- Thermodynamics indicate that low silica activity glasses stabilise zirconolite.

ARTICLE INFO

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ABSTRACT

Zirconolite glass-ceramic wasteforms were prepared using a suite of Na_2O–Al_2O_3–B_2O_3–SiO_2 glass matrices with variable Al:B ratios. Zirconolite was the dominant crystalline phase only for the most alumina rich glass compositions. As the Al:B ratio decreased zirconolite was replaced by sphene, zircon and rutile. Thermodynamic data were used to calculate a silica activity in the glass melt below which zirconolite is

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Special Issue "Materials for Nuclear Waste Immobilization"

- Special Issue Editors
- Special Issue Information
- Keywords
- Published Papers

materials

A special issue of *Materials* (ISSN 1996-1944).

Deadline for manuscript submissions: **31 May 2018**

Nuclear energy is clean, reliable and competitive with many useful applications among which power generation is the most important, where it can gradually replace fossil fuels and avoid massive pollution to the environment. A useless by-product, resulting from utilization of nuclear energy in both power generation and other applications, such as in medicine, industry, agriculture, and research, is nuclear waste.

Safe and effective management of nuclear waste is crucial in ensuring sustainable utilization of nuclear energy. Nuclear waste must be processed to make it safe, which includes its conditioning, so it is immobilized and packaged before storage and disposal. Immobilization of waste radionuclides in durable wasteform materials provides the most important barrier to contribute to the overall performance of any storage and/or disposal system. Materials for nuclear waste immobilization are, thus, at the core of multibarrier systems of isolation of radioactive waste from environment aimed to ensure long term safety of storage and disposal.

This Special Issue aims to analyze the materials currently used, as well as novel materials for nuclear waste immobilization, including technological approaches utilized in nuclear waste conditioning pursuing to ensure efficiency and long-term safety of storage and disposal systems. It will focus on cementitious materials, geopolymers, glasses, glass composite materials, and ceramics developed and used in nuclear waste immobilization with performance of such materials of the utmost importance.

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Special Issue Editors

Guest Editor
Dr. Michael I Ojovan
Immobilisation Science Laboratory, Department of Materials Science and Engineering, University of Sheffield, Mappin Street, Sheffield S1 3JD, United Kingdom
Website | E-Mail
Interests: structure and properties of amorphous materials including the viscosity and glass transition; materials for nuclear waste immobilization; waste processing technologies

Guest Editor
Prof. Neil C. Hyatt
Immobilisation Science Laboratory, Department of Materials Science and Engineering, University of Sheffield, Mappin Street, Sheffield S1 3JD, United Kingdom
Website | E-Mail
Interests: radioactive waste management and disposal; advanced nuclear materials; structure–property relations in mixed metal oxides

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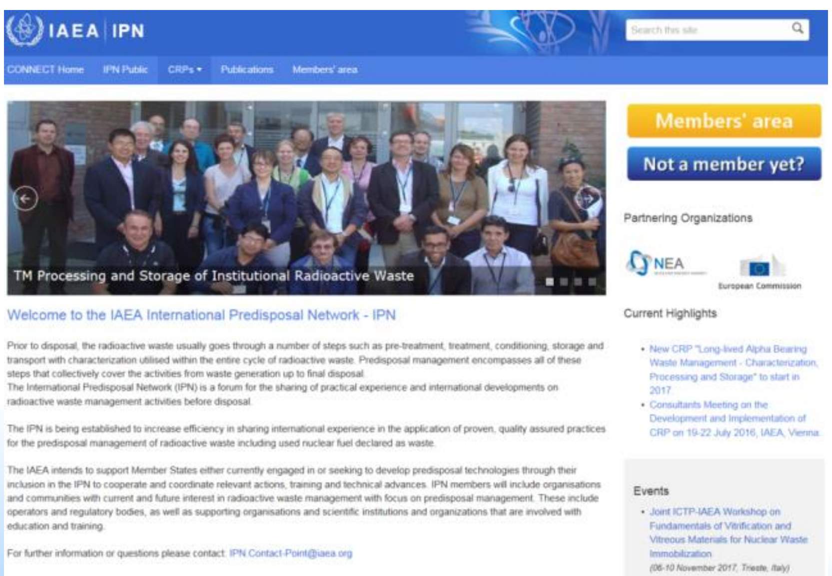
IAEA support activities



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Vitreous Materials for Nuclear Waste Immobilisation and IAEA Support Activities

Rebecca A. Robbins and Michael I. Ojovan
Department of Nuclear Energy, International Atomic Energy Agency,
Vienna International Centre, PO Box 100, 1400 Vienna, Austria

ABSTRACT

Vitreous materials are the overwhelming world-wide choice for the immobilisation of HLW resulting from nuclear fuel reprocessing due to glass tolerance for the chemical elements found in the waste as well as its inherent stability and durability. Vitrification is a mature technology and has been used for high-level nuclear waste immobilization for more than 50 years. Borosilicate glass is the formulation of choice in most applications although other formulations are also used e.g. phosphate glasses are used to immobilize high level wastes in Russia. The excellent durability of vitrified radioactive waste ensures a high degree of environment protection. Waste vitrification gives high waste volume reduction along with simple and cheap disposal facilities. Although vitrification requires a high initial investment and then operational costs, the overall cost of vitrified radioactive waste is usually lower than alternative options when account is taken of transportation and disposal expenses. Glass has proven to be also a suitable matrix for intermediate and low-level radioactive wastes and is currently used to treat legacy waste in USA, and NPP operational waste in Russia and South Korea. This report is also outlining IAEA activities aiming to support utilisation of vitreous materials for nuclear waste immobilisation.

Summary & Conclusions

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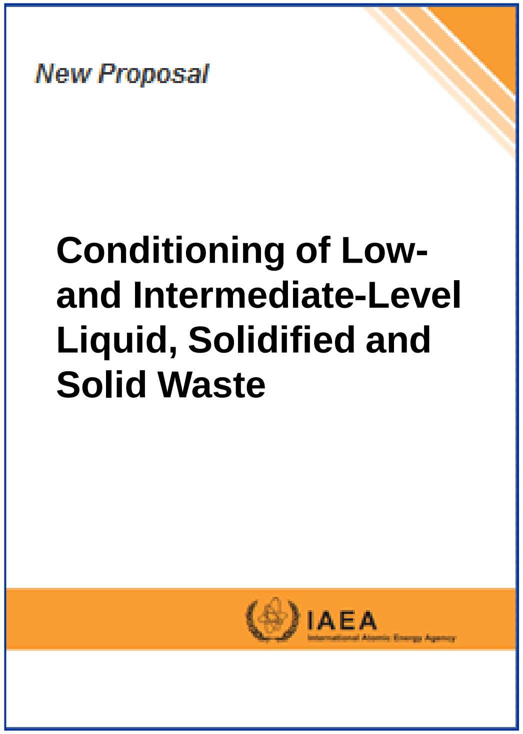
- Conditioning improves safety and security, e.g., by converting waste into a more stable form to contain radionuclides for extended periods until it no longer pose a risk to workers, public, and the environment.
- LILW conditioning produces wasteforms and waste packages that meet the technical and regulatory requirements of the respective Member States for the safe and secure storage, transportation and disposal (including compliance with the disposal site safety case).
- A new IAEA Handbook “Conditioning of Low- and Intermediate-Level Liquid and Solid Waste” has been prepared to publication among eight IAEA handbooks intended to provide guidance for evaluating and implementing various characterisation and radioactive waste processing and storage technologies before final disposal.
- The Conditioning Handbook will presumably be published in the first half of 2018.



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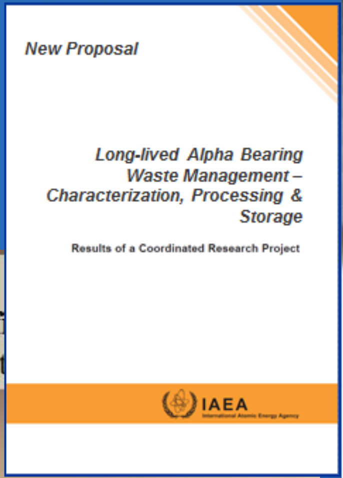

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