Course Programme

Treatment, Conditioning and New Matrices for Radioactive Waste

DAY 1 - Waste Streams, Radiological Characterisation and Treatment

09:00–09:15 Welcome and Course Overview

Speaker: CIEMAT – Specialized Training Unit

- Introduction of instructors and participants
- Learning objectives, course structure and logistics
- Q&A format and workshop approach

Session 1 - Fundamentals and Context

09:15–10:45 (90 min)

Speaker: ENRESA

- **Integrated predisposal chain:** waste generation or retrieval → inventory and characterisation → pretreatment → treatment → conditioning → interim storage → disposal
- **Decision drivers:** waste hierarchy, volume reduction, Waste Acceptance Criteria, safety, operability, cost, technology readiness and sustainability
- **Operational versus decommissioning waste**: origin, available process knowledge, scale, heterogeneity and implications for management
- **Main waste-stream families:**
    - Ion-exchange resins: wet and spent resins, activity levels, salt content and drying needs
    - Liquid waste: aqueous streams, sludges and evaporator concentrates
    - Organic liquids: oils, solvents and mixed organic streams
    - Solid operational waste: cartridge filters, compactable solids and miscellaneous waste

    - Metallic waste: contaminated versus activated metals
    - Decommissioning waste: concrete, rubble, soils, mixed materials and NORM-related waste
- **Legacy and unconventional waste:** historic waste campaigns, orphan waste, heterogeneous drums, incomplete records and historic waste forms
- **Characterisation needs for route selection:**
    - Waste origin and process knowledge
    - Physical form, particle size, homogeneity and free-liquid content
    - Chemical composition, salts, organics, hazardous constituents and compatibility issues
    - Radiological inventory, dose rate and key radionuclides
    - Available data, estimated data, unknowns and critical uncertainties
    - Information required for treatment selection, process control, WAC compliance and waste-package qualification

Session 2 - Radiological Characterisation as a Decision Driver for Treatment and Conditioning

11:00–12:15 (75 min)

Speaker: Westinghouse

- Role of radiological characterisation in waste-management decisions
- Developing waste inventories: easy-to-measure versus difficult-to-measure radionuclides
- Sampling strategies, representativeness, Data Quality Objectives, heterogeneity and variability
- Development and use of scaling factors
- Effects of characterisation uncertainty on treatment selection, conditioning strategy and WAC compliance

12:15–13:15 Lunch

Session 3 - Pretreatment and Decontamination

13:15–14:30 (75 min)

Speaker: NNL

- Sorting and segregation using radiological and physical criteria
- Metal and surface decontamination: chemical, electrochemical and mechanical techniques
- Decontamination of structures: washing, blasting and chemical methods

- Decision-making for reuse, recycling, clearance or further treatment
- Decontamination as an enabler for volume reduction and waste reclassification

14:30–14:45 — Coffee break

Session 4A - Treatment Routes for Liquids and Resins

14:45–15:30 (45 min)

Speaker: To be confirmed

- Evaporation, filtration, centrifugation and precipitation for liquid waste
- Ion exchange and treatment of evaporator concentrates
- Drying and dewatering approaches
- Treatment options for spent ion exchange resins
- Thermal and chemical alternatives to conventional treatment
- Influence of the radiological inventory on process selection and operating constraints

Session 4B - Treatment Routes for Organic Liquids, Solids, Metals and Soils

15:30–16:15 (45 min)

Speaker: To be confirmed

- Organic liquids: incineration, oxidation processes and supercritical water oxidation
- Solid waste and filters: compaction, incineration and preparation for encapsulation
- Metallic waste: decontamination, size reduction, melting and recycling pathways
- Soils and rubble: washing, segregation, crushing and sorting
- Secondary-waste generation and off-gas management

Workshop 1 Selecting Pretreatment and Treatment Routes

16:15–17:45 (90 min)

Facilitators: Treatment-routes speakers

Participants work in teams with a realistic facility inventory, including operational, decommissioning and legacy waste streams. Each team selects and justifies pretreatment and treatment routes, considering waste

characteristics, radiological inventory, technical feasibility, volume reduction, secondary waste and compatibility with the intended conditioning route.

DAY 2 - Conditioning and Waste Forms

Session 1 - Conditioning Principles

09:00–10:00 (60 min)

Speaker: to be confirmed

- Immobilisation, containment and long-term durability
- Compatibility with storage, transport and disposal
- WAC: mechanical stability, leach resistance, free-liquid limits, handling and labelling
- The waste form within the multi-barrier safety concept
- Waste loading, homogeneity, setting behaviour and gas generation

10:00–10:15 - Coffee break

Session 2A Conventional Cement-Based Systems

10:15–11:00 (45 min)

Speaker: CEA

- Ordinary Portland cement, blast-furnace slag blends and calcium aluminate cement
- Hydration chemistry, pore-solution alkalinity and key performance properties
- Applications for resins, sludges, liquids and evaporator concentrates
- Compatibility challenges: salts, organics, retardation and heat of hydration
- Quality assurance and quality control: mixing, workability, curing and mechanical performance

Session 2B — New Cementitious Matrices for Emerging Waste Challenges and Supply Resilience

11:00–11:45 (45 min)

Speaker: CSIC

- Drivers for developing new cementitious matrices: changing waste inventories, problematic waste chemistries, sustainability requirements and future industrial constraints
- Advanced and low-pH cementitious systems for repositories with severe geochemical requirements
- Tailored binders for high-salt, sulphate-, nitrate-, borate- or organic-bearing waste streams
- Hybrid binders, supplementary cementitious materials and alkali-activated / geopolymer systems
- Performance targets: waste loading, durability, leach resistance, gas generation, heat management and long-term compatibility
- **Supply resilience for conditioning materials:** reducing dependence on conventional clinker and specific raw materials; use of alternative precursors, industrial by-products and locally available materials
- Qualification and scale-up: reproducibility, quality assurance, industrial implementation, procurement constraints and integration into the safety case

11:45–12:00 — Coffee break

Session 3A — Legacy and Unconventional Wastes

12:00–12:45 (45 min)

Speaker: ANDRA

- Definition and typology of legacy and unconventional waste
- Historical conditioning campaigns, orphan waste and heterogeneous drums
- Historic bituminised and polymer-encapsulated waste
- Reconstruction of incomplete inventories and records
- Sampling, characterisation, retrieval and retrievability challenges
- Decision options: retain, reinforce, overpack, recondition or reprocess

12:45–13:45 — Lunch

Session 3B — Polymeric Matrices and Bitumen as Organic Waste Forms

13:45–14:45 (60 min)

Speaker: ANDRA

Polymeric matrices

- Thermosetting systems: epoxy and polyester
- Thermoplastic systems: polyethylene and related materials
- Superabsorbent polymers and solidification of liquid waste
- Curing, viscosity, homogeneity, void control and QA/QC
- Radiation, thermal and chemical ageing
- Implications for storage, disposal and WAC compliance

Bitumen

- Properties relevant to waste immobilisation
- Typical waste streams: evaporator concentrates, selected sludges and ion exchange resins
- Process and waste-loading considerations
- Gas generation, thermal behaviour, water interaction and long-term performance
- Role of bituminised waste in legacy inventories

14:45–15:00 — Coffee break

Session 4 - Waste Stream – Treatment & Matrix Matching

15:00–16:00 (60 min)

Speaker: to be confirmed

- Resins and sludges: drying plus cementation versus direct encapsulation
- Evaporator concentrates and liquid residues: conventional cementitious, new cementitious, mineral and polymeric options
- Organic liquids: destruction-first versus direct encapsulation
- Cartridge filters and solid operational waste: grouting, encapsulation and overpacking
- Metals after decontamination or melting: conditioning options and volume implications
- Decommissioning and legacy materials: sorting-first strategies, bulk conditioning and reconditioning decisions
- Selection framework: WAC, waste–matrix compatibility, volume, operability, maturity, supply security, cost and sustainability

Workshop 2 — Selecting Conditioning Matrices

16:00–17:30 (90 min)

Facilitators and expert contributions: Enresa, CEA, CSIC, ANDRA, Westinghouse

Teams select and justify a conditioning solution for representative operational, decommissioning and legacy waste streams. Each proposal must address:

- Radiological inventory and WAC compliance
- Waste–matrix compatibility
- Process feasibility and QA/QC
- Waste loading and volume impact
- Long-term performance and gas-generation considerations
- Availability and supply resilience of the selected conditioning materials
- At least one sustainability indicator

17:30–17:45 — Course Wrap-up and Q&A

Speakers: CIEMAT Specialised Training Unit

DAY 3 – Technical visit to El Cabril radioactive waste disposal facility

Workshops

Workshop 1: Case Studies: Selecting Pretreatment and Treatment Routes

Day 1: 16:15–17:45 (90 min)

Participants work in five teams of five. Each team evaluated a realistic waste stream case: spent ion-exchange resins, a high-salt liquid concentrate, mixed organic liquids, contaminated metal waste, or a heterogeneous legacy drum. Teams select and justify a pretreatment and treatment route, considering waste characterisation, operational constraints, secondary-waste generation, volume reduction and compatibility with subsequent conditioning.

Objective: To design a pretreatment and treatment route from the untreated waste stream to a treated waste suitable for conditioning.

Group	Case Study	Main Decision
1	**Spent ion-exchange resins**	• Select dewatering/drying and a treatment route • Identify a compatible conditioning matrix
2	**High-salt liquid waste and evaporator concentrate**	• Define the additional characterisation required • Select concentration, separation and treatment steps
3	**Mixed organic liquids**	• Compare incineration, Fenton oxidation and SCWO • Justify off-gas management and secondary-waste treatment
4	**Contaminated metallic waste**	• Define the route for segregation, decontamination, size reduction, melting/recycling or disposal
5	**Heterogeneous legacy drum**	• Develop a safe characterisation and handling strategy • Decide between overpacking, retrieval, segregation or reprocessing

Deliverable for Each Group

Each group prepares a **Treatment Decision Sheet** or one **presentation slide** including:

1. Waste description and critical uncertainties
2. Additional characterisation data required
3. Selected pretreatment and treatment route
4. One discarded alternative and the reason for rejecting it
5. Operational risks and expected secondary waste
6. Expected final state and a potentially compatible conditioning matrix

Task	Time
Case briefing, teams and expected deliverable	10 min
Team analysis and preparation	40 min
Five group presentations	25 min
Expert feedback and discussion	10 min
Synthesis	5 min

Workshop 2: Case Studies: Selecting and Qualifying Conditioning Matrices

Day 2: 16:00–17:30 (90 min)

The same five teams receive the treated output from their Day 1 case, together with an additional constraint. They compare and select conventional and new cementitious systems, mineral matrices, polymers or bitumen, as applicable. Teams justify their decision against WAC, waste–matrix compatibility, waste loading, long-term performance, QA/QC needs, supply resilience and sustainability.

Objective: To select, justify and outline the qualification of a conditioning matrix for the treated waste generated in Workshop 1.

Group	Treated-Waste Case	Main Decision	Additional Constraint
1	**Dried ion-exchange resins**	Compare conventional OPC, blended systems, geopolymers/AAM, polymers and bitumen	Free-liquid limit and potential for gas generation
2	**Salt-rich evaporator-concentrate residue**	Compare OPC/BFS, a tailored cementitious formulation, a low-pH matrix or a geopolymer	High nitrate/borate content and a supply constraint affecting a conventional binder constituent
3	**Ash, spent adsorbent or secondary residues from organic-liquid treatment**	Select a final conditioning matrix and determine the waste loading	Leach-resistance requirement and final-volume minimisation
4	**Decontaminated metal pieces and filter waste**	Compare direct encapsulation, grouting, overpacking or additional treatment	Handling stability, void control and waste-acceptance requirements
5	**Historic bituminised or polymer-encapsulated waste**	Decide whether to retain, overpack, reinforce, recondition or reprocess	Uncertain inventory, signs of ageing and a retrievability requirement

Deliverable for Each Group

Each group prepares a **Conditioning Matrix Decision Sheet** including:

- Preferred matrix and one realistic alternative that was rejected
- Waste–matrix compatibility and applicable WAC
- Waste loading, free-liquid control and volume impact
- Expected long-term performance: gas generation, leaching, thermal/radiolytic stability and mechanical integrity
- Required QA/QC and qualification tests
- Sustainability considerations and one raw-material supply-resilience consideration

Task	Time
Case briefing, teams and expected deliverable	10 min
Team analysis and preparation	40 min
Five group presentations	25 min
Expert feedback and discussion	10 min
Synthesis	5 min