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DEVELOPMENT, OPTIMIZATION, AND HARMONIZATION OF INNOVATIVE TECHNIQUES FOR RADIOACTIVE WASTE CHARACTERIZATION WITHIN THE EURAD-2 PROGRAMME

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Introduction

The **ICARUS (Innovative Characterisation Techniques for Large Volumes)** Work Package 5 (WP5) in the EURAD-2 partnership focuses on advancing, optimizing and harmonizing cutting-edge techniques for characterising the radiological, physical, and chemical properties of low and intermediate-level mixed radioactive waste (LLW/ILW). These characterisation capabilities are essential for ensuring safe implementation of radioactive waste management programs across Europe. The research integrates laboratory-scale **destructive techniques (DT)** with field-deployable **non-destructive techniques (NDT)**, establishing reliable correlations through **scaling factors (SF)** for both raw waste materials and packaged waste containers.

Objectives of the work

- Identification of relevant **use cases** related to decomissioning sites, to develop cutting-edge techniques and methods for an industrial application.
- Development of characterization methodologies for heterogeneous mixed wastes from decommissioning, to acquire accurate radiological and chemical inventory necessary for determining the pre-disposal waste management.
- Identification of most relevant radionuclides, including the limitations and difficulties that remain for their proper characterisation.

Methodology

Use cases

Relevant use cases have been identified to address the specific industrial needs, thanks to WMO partners and the engagement of End Users from several Member States:

1. To achieve fast and sufficiently accurate **gamma activity distribution** in complex large packages, NDTs require innovation and optimization to be proficiently implemented in industrial applications, encompassing decommissioning and ongoing operational processes.
2. To improve and simplify the inventory of **physical-chemical properties** and alpha emitters compared to current expensive DT and high uncertainty SF methods, the optimization of NDT needs to be investigated in relevant industrial scenarios (decommissioning/operational processes).
3. To improve sensitivity, accuracy, uncertainty and cope with expensive and time-consuming conventional radiochemical analysis, cutting-edge DTs need to be developed for determining long-lived **Difficult To Measure (DTM) radionuclides** (C-14, Cl-36, Ca-41, Se-79, Zr-93, Mo-93, Tc-99, Pd-107, Cs-135, Cm-243, Cm-244) in decommissioning/operational samples to develop a comprehensive inventory.
4. To lower the uncertainties and improve accuracy and reliability to meet ever stringent **requirements set by national regulators** for raw mixed waste, the SF approach needs to be thoroughly investigated.

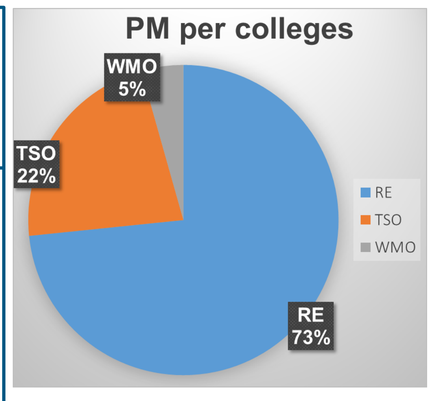
29 Partners + 20 End Users + 11 Stakeholders

Waste Management Org.

Technical Support Org.

Research Entities

Associated Partners



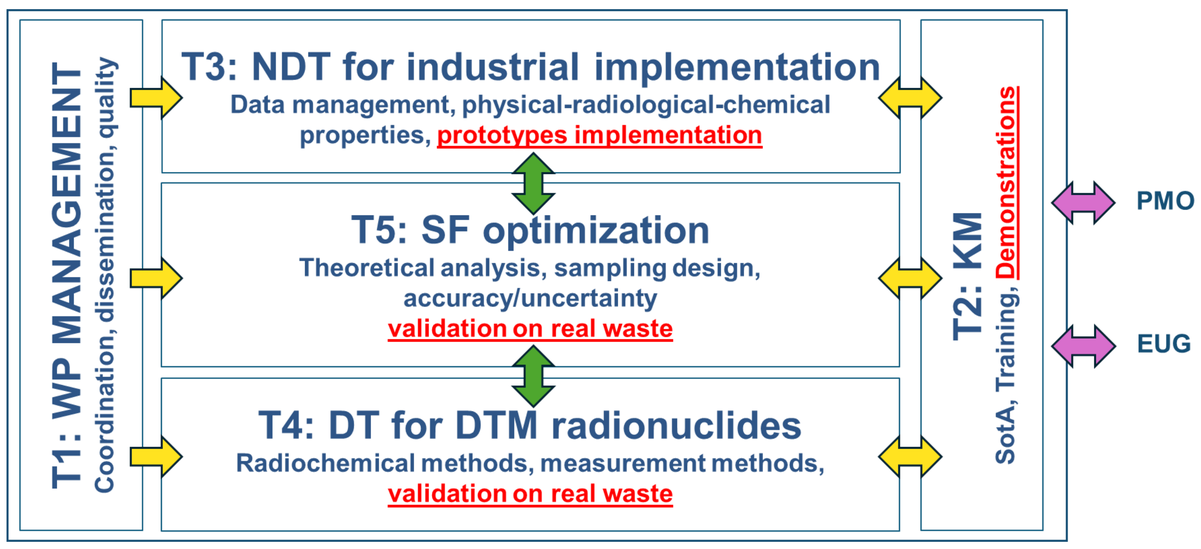
Duration

5 years

Budget

4.4 M€ (50% EC)

Expected results



Task 1 – Management and coordination (POLIMI)

- Organisation of **periodical meetings** for planning, coordinating, and monitoring the WP activities;
- **Dissemination** of results, interaction with End-Users and stakeholders;
- Ensure **quality control** and **risk management**, while assessing the achievement of key performance indicators.

Task 2 – Knowledge Management (SSTC NRS)

- Writing of **State-of-the-Art documents**, with a comprehensive list of physical/chemical/radiochemical/radiological/statistical techniques;
- Identification and development of **specific training materials** in support of dedicated education and training activities;
- Organization of face-to-face and on-line **training and demonstrations**.

Task 3 – NDT design for industrial implementation (NRG)

- Development of **real-time data management** with AI-driven solutions, Machine vision and ML algorithms;
- Development of **flexible, robust, and modular NDT** for the characterisation of physico-chemical-radiological properties, e.g. density, gamma-neutron-alpha emitters distribution in large-volume packages, alkali-silica reaction in the long time-scale;
- Development of **prototypes** and demonstration of their accuracy, reliability, and applicability in industrial decomissioning scenarios with respect to reference systems.

Task 4 – Design of DT for DTM radionuclides (DTU)

- Development of rapid and effective **radiochemical methods** to recover DTM radionuclides (C-14, Cl-36, Ca-41, Se-79, Zr-93, Tc-99, Mo-93, Pd-107, Cs-135, Cm-243, Cm-244) from the matrix (alloys, metals, concrete, graphite, and resins) and remove all interfering elements and isotopes;
- Development of quick, sensitive, and accurate **measurement methods** (LSC, AMS, ICP-MS) for the abovementioned long-lived DTM radionuclides;
- Validation and demonstration of the developed methods on **real waste samples** provided by project partners.

Task 5 – SF optimization (ENRESA)

- Identification of main processes that affect the **theoretical model** uncertainty, accuracy and precision by applying the conducive parameters;
- Definition of the best **sampling design** to improve the SF uncertainty, accuracy and precision by innovative statistical data processing techniques;
- Assessment of SF applicability depending on the **degree of heterogeneity** of (legacy) waste and WAC prior to its disposal;
- Validation of the developed multiparametric nuclide vector models to the caracterisation of **real waste streams**.

Conclusions

ICARUS will contribute to advancing toward more efficient, accurate, and cost-effective characterisation methodologies that support the safe and sustainable management of radioactive waste by addressing the identified technical gaps and pursuing the identified use cases, with a continuous interaction with the End Users.

Acknowledgment

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