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**RESULTS FROM THE EURAD ROUTES WORK PACKAGE - TOWARDS FUTURE  
EUROPEAN COLLABORATION ON RADIOACTIVE WASTE MANAGEMENT – 24662**

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**ABSTRACT**

The ROUTES Work Package (WP) is one of the two strategic studies being conducted as part of the European Joint Programme on Radioactive Waste Management (EURAD) studying waste management routes, from cradle to grave, in Europe.

The objectives of ROUTES are to (1) provide an opportunity to share experience and knowledge on waste management routes between interested organisations (from different countries, with programmes at different stages of development, with different amounts and types of radioactive waste to manage), (2) identify safety-relevant issues and their R&D needs associated with the waste management routes (cradle to grave), including the management routes of legacy and historical waste, considering interdependencies between the routes, (3) describe and compare the different approaches to characterisation, treatment and conditioning and to long-term waste management routes, and identify opportunities for collaboration between member-states. The expected output is the identification of R&D needs and opportunities for collaboration between member states.

The ROUTES WP encompasses a diverse range of tasks, each addressing distinct topics within the waste management domain. The comprehensive exploration has covered the following key areas: “challenging waste”, waste characterization, waste acceptance criteria, management solutions for Small Inventory Member States (SIMS), shared solutions, incorporating the valuable insights and perspectives of civil society. The recommendations are a result of the insights and achievements obtained from the deliverables and milestones arising from these tasks.

In the area of addressing radioactive waste challenges in Europe, the ROUTES WP has produced significant results besides recommendations. It enabled a comprehensive understanding of challenges related to predisposal issues at the European level as well as enabled to facilitate the sharing of knowledge and technologies. It gave an opportunity for underrepresented voices to tackle their own challenges and access potential solutions, and offered civil society representatives to bring their own perspective. Through

networking, valuable connections were built that emphasized the importance for Small Inventory Member States (SIMS) to work with Large Inventory Member States (LIMS). Moreover, the work has led to the identification on one hand of potential stakeholders who are tackling similar waste-related challenges, and, on another hand, the identification of potential customers interested in developing innovative treatment approaches for such waste.

Furthermore, the implemented initiatives have enhanced visibility on crucial topics, such as shared solutions. This visibility has created opportunities for partnerships, especially with countries that may lack the resources to join the European Repository Development Organization (ERDO) association, which focuses on advancing shared waste management options including disposals, to get up-to-date information on the latest developments in this field. By fostering these collaborations, the ROUTES WP aims to promote global cooperation in effectively addressing the complex issue of radioactive waste disposal.

Finally, the ROUTES WP enabled the identification of twenty-two recommendations on Research and Development, strategic studies and knowledge management activities for future European collaboration.

## **INTRODUCTION**

The ROUTES project, one of the two strategic studies being conducted as part of EURAD, is nearing its conclusion. Launched in June 2019, the five-year initiative is set to conclude in May 2024.

The primary goals of the ROUTES WP are to facilitate the exchange of knowledge and experience among various MS, with different developmental stages of their respective programs and radioactive waste types and levels, to identify safety-related R&D needs as well as to promote the comparison of approaches and collaboration. To fulfill these objectives, the project is structured around several tasks, each dedicated to specific aspects within the field of waste management. The ROUTES WP is organized into seven tasks to delve into the diverse challenges and potential solutions, as illustrated in Figure 1:

- Task 1: Coordination, state-of-the-art and training materials.
- Task 2: Identification of challenging wastes to be collaboratively tackled within EURAD.
- Task 3: Description and comparison of radioactive waste characterization approaches.
- Task 4: Identification of Waste Acceptance Criteria (WAC) used in EU Member-States for different disposal alternatives in order to inform development of WAC in countries without WAC disposal facilities.
- Task 5: Radioactive Waste Management (RWM) solutions for small amounts of wastes (focusing on disposal strategies for small-inventory Member-States).
- Task 6: Description of the state-of-the-art of shared solutions in European countries for characterization, treatment, storage and disposal and planned sharing of facilities between Member-States, as well as identification of gaps and R&D requirements.
- Task 7: Interactions with Civil Society.
- Task 8: ROUTES Extension on the evaluation of the possible waste management solutions for Member States without WAC and with small inventories (SIMS).

The eighth task has been included in the ROUTES’s work within EURAD second wave WPs selection process from June 2021 with the objective to strengthen collaboration between SIMS and LIMS and to ensure knowledge transfer with respect to the SIMS needs.

This comprehensive project, involving thirty-six organizations from twenty-one countries and with a budget of €2 million, is designed to deliver seventeen deliverables. More importantly, the work conducted has led to the identification of twenty-two knowledge management (KM), Research and Development (R&D) and Strategic Study (StSt) recommendations; KM encompasses the development of guidance, SotA and training whereas StSt encompasses networking on methodologies and common challenges. Most tasks have successfully produced their conclusions and recommendations. Last findings are expected on the evaluation of possible waste management solutions for Member States (MS) without WAC and with small inventories (SIMS). This paper presents the context and the stakes linked to these recommendations.

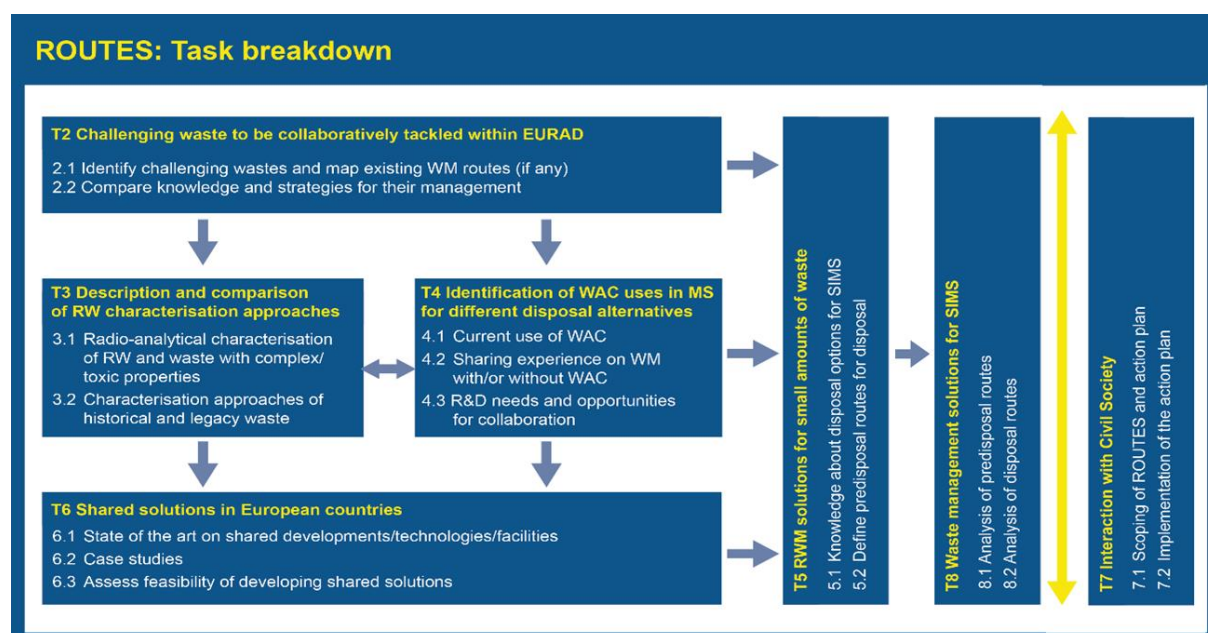


Figure 1. ROUTES task breakdown.

## APPROACH / METHODOLOGY

The ROUTES project mainly relies on partners’ inputs and data collection. Year 1 focused on gathering data on RWM, especially related to waste identified as challenging, through a comprehensive questionnaire distributed to ROUTES participants as well as workshops organization. This included national waste classification, inventory, disposal facilities, and more. Year 2 involved analyzing case studies to compare approaches and strategies adopted by member states to cope with issues related to these challenging wastes. This work has enabled ROUTES partners to identify issues which were further analyzed, notably related to the retrieval of poorly characterized legacy waste from a predisposal or disposal facility, the implementation of specific waste management solutions in the absence of well-defined WAC or the development of innovative or shared solutions for member states that have only limited amounts of waste to manage. In Years 3 to 5, the project concentrates on the identification and prioritization of the common R&D needs related to the management of challenging wastes and the opportunities for collaboration between MS.

## WORK CONDUCTED BY TOPIC AND IDENTIFIED RECOMMENDATIONS

The ROUTES work enabled the identification of twenty-two recommendations as displayed in Figure 2.

Those recommendations are divided into seven topics: interactions with civil society & safety culture, international cooperation, disposal strategies, concept selection, development of Waste Acceptance Criteria (WAC), characterization and treatment & conditioning.



Figure 2. Overview of Recommendations Identified During the ROUTES Project.

### Interactions With Civil Society & Safety Culture

In the context of implementing the Aarhus Convention for RWM, that stands on three pillars (access to information, effective public participation and access to justice), two significant issues have arisen: the lack of adequate resources and of an access to independent expertise for civil society actors, impacting their participation, and the variations in inclusivity and information access across European Union (EU) member states [1]. To address these challenges, two ROUTES recommendations have been proposed:

- The "Comparison of approaches regarding implementation of access to resources and inclusivity" (StSt-1) would aim to develop a model that can be identified as appropriate for diverse actors and recommended for adoption across the European Union, contingent on whether member states possess small or large waste inventories. By providing a reliable basis for engaging with various actors, it would enhance trust and knowledge management among them, fostering inclusivity and offering governance solutions tailored to the needs, while also enabling comparisons of Aarhus Convention implementation across Europe.
- The "Development of guidance for effective public access to information" (KM-1) would aim to develop a model for ensuring effective public access to information concerning RWM and a model for engaging public consultations with independent experts, in the objective to improve transparency and

efficiency of public participation in decision-making processes, facilitate trust among actors by simplifying the process of verifying information, which can lead to potential cost optimization through greater public control over the financing of projects. This could also lead to the early identification of issues of importance to the public and an increase of the information volume gathered for the benefit of future generations.

Another area of interest addressed in ROUTES work involved maintaining a robust safety culture across generations, which is challenging but crucial. An intergenerational management approach is essential for ongoing waste monitoring and maintenance, with a focus on continuous knowledge management and knowledge transfer. This would ensure future generations to uphold safety standards and effectively handle radioactive waste with the aim of enabling the retrieval, recharacterization, and repackaging of waste, if necessary, in the future, by preserving safety culture in this evolving field. To achieve this, ROUTES recommended the “Identification of challenges related to long-term/rolling stewardship” (StSt-2) in order to clarify the long-term safety and governance of waste disposal to ensure that safety standards are maintained, and how knowledge is passed from generation to generation.

### **International Cooperation**

EU member states can be divided into LIMS (such as Belgium, Bulgaria, the Czech Republic, France, Finland, Germany, Hungary, Italy, Lithuania, Romania, Slovakia, Spain, Sweden, United Kingdom) and SIMS (such as Austria, Croatia, Cyprus, Denmark, Estonia, Greece, Ireland, Latvia, Luxembourg, Malta, the Netherlands, Poland, Portugal, and Slovenia). Member states with advanced programs, mostly LIMS, accumulated substantial expertise, knowledge, and innovative approaches in waste management, both in pre-disposal and disposal phases. Their experiences and practices, including successes, lessons learned from challenges, can greatly benefit member states, whose nuclear program is still in early stages of development. To facilitate this knowledge transfer, tools like dedicated platforms, organizational structures, and mobility programs as well as good practices and training are necessary to share knowledge and practices [2] [3]. To address this challenge, ROUTES enabled to identify the “Strengthen collaboration within Communities of Practice between SIMS and LIMS” (KM-2) recommendation which plans the establishment of a guidance on predisposal routes of challenging wastes, including all aspects of waste management, from initial inventory to characterization, treatment, conditioning methods, and disposal options. This would improve the efficiency, affordability, and safety of disposal strategies for SIMS, and establish a comprehensive knowledge reference covering waste management throughout its life cycle, from pre-disposal to disposal.

Considering the limited inventories of challenging wastes that SIMS have to deal with, which often encompass various waste types in small quantities, elaboration of individual solutions may not be cost-effective. ROUTES-work highlighted that solutions often exist but are not available where needed [2] [4]. Moreover, the cross-border transportation of radioactive waste requires varying permits and is resource-intensive. Mobile facilities, transported to the waste site, can mitigate these challenges. Research is thus needed to develop mobile facilities for conditioning in specific matrices and for testing such facilities, notably for raw or conditioned legacy waste. Collaboration set-ups are time-consuming, and challenging due to requiring intergovernmental agreements. Successful collaborations depend on political relationships between involved member states and basic ethical and legal principles, like level playing field, common safety culture and agreed common legal framework [5]. Confidence between involved partners enhance collaboration success. To address these challenges, two ROUTES recommendations have been proposed:

- The “Development of a mobile facility for RAW characterization, treatment or conditioning” (R&D-1) would allow cost-effective solutions for SIMS.
- The “Harmonization of procedures to facilitate collaborations between MS” (StSt-3) aims at clarifying the complexities associated with determining the necessary procedures and permits, which can be both time-consuming and resource-intensive, when it comes to collaborate between member states. Simplifying this process requires harmonizing the various steps needed to enhance the possibility of operating commercial treatment facilities outside national borders, help reducing storage periods and improve safety, and encourage the possibility of using shared storage or disposal facilities through harmonized procedures.

### **Disposal Strategies**

The work conducted under ROUTES allowed to particularly highlight gaps in terms of disposal strategies for so-called “challenging waste”; it enabled a comprehensive review of radioactive waste classification and categorization approaches, an in-depth study of challenging waste streams specific to each country, and an analysis of case studies on management strategies for these types of challenging waste [6]. “Challenging waste” can be defined as waste for which no current or applicable solution for their safe management is available, including difficulties or the absence of at least one step in the waste lifecycle. Based on this definition, 11 challenging wastes have been identified and various reasons have led to consider them as challenging one (bitumized waste, decommissioning waste, Disused sealed radioactive sources (DSRS), graphite, organic waste, particular spent fuel, sludges, spent ion exchange resin (SIERs), uranium/radium/thorium-bearing waste, waste containing chemotoxic substances, and waste containing reactive metals). Among those reasons, two recurring ones are related to the fact that the considered “challenging waste” (i) are not meeting WAC for existing/planned facilities or (ii) don’t have any disposal solution. Based on this observation, an emphasis was placed on predisposal and disposal needs for a better management of challenging waste, as well as on the current use of WAC and sharing experiences on waste management with and without WAC. Among the discussions, member states often highlighted the fact that they have to manage challenging waste which do not meet WAC for existing or planned facilities, because of their inventory or properties [6] [7]. To address these challenges, two ROUTES recommendations have been proposed:

- The "Common analysis on disposal strategy for waste that doesn't meet WAC for existing/planned facilities" would help identifying new options and potential alternatives, and consequently, reduce the number and range of challenging waste with no clear disposal routes, obtain an overview/strategy of national contexts for managing U/Ra/Th bearing wastes and how to dispose of them, share experience and best practices, notably having better insight into available treatment, conditioning options and disposal routes.
- The "Common analysis on disposal strategy for particular spent fuel and depleted uranium" takes into account that the disposal of particular spent fuel and depleted uranium remains an open question and could represent a challenge in the coming years. In line with the previous one, the implementation of this recommendation would aim to identify the needs and expectations of interested member states in terms of disposal of particular spent fuel and depleted uranium. This would help obtaining an overview of current national contexts and potential strategies that would help define, among MS, common strategies that could be implemented in the future.

ROUTES also addressed the issues related to the management of waste from small modular reactors (SMRs) and advanced reactor concepts, which represent promising solutions to the world's growing energy

needs. The discussion surrounding SMRs encompasses both LIMS and SIMS. The proposed objectives for an initiative like a "European SMRs Partnership" are to promote the development of an industrial supply chain within Europe, promote a harmonized licensing process, and establish a strategic research agenda. The recommendation "Develop strategies for the management of SMR waste management" (StSt-6) is poised to enhance our understanding of the impact of SMR implementation on pre-disposal and disposal strategies and to evaluate the influence of SMR back-end processes on the pre-disposal and disposal routes for SIMS.

The discussions within ROUTES also tackled the issue of European Green Deal, which emphasizes sustainability and environmental responsibility and might carry significant implications for the RWM and spent nuclear fuel within European MS. These implications extend broadly across radioactive waste and spent fuel management practices in Europe, demanding adjustments in legislation and policies, the integration of circular economy principles, the harmonization of requirements, and diligent financial planning to ensure that the nuclear industry aligns with the sustainability objectives outlined in the European Green Deal. The recommendation "Impact of the EU Green Deal on radioactive waste management" (StSt-7) aims to enhance the implementation of Green Deal requirements in the RWM field, fostering increased cooperation among stakeholders at both the national and international levels, while also providing guidance on the implications of the Green Deal for MS.

### **Concept Selection**

Several SIMS possess relatively small quantities of waste; therefore, the issue of final disposal is challenging. Moreover, SIMS typically lack the expertise, human and financial resources required to formulate a safety case, notably for deep geological disposal, as most of the expertise and research in radioactive waste disposal lies within LIMS. To address this challenge, a more suitable approach, such as the concept of deep borehole disposal, appears suitable for accommodating smaller quantities of waste [2]. To that end, ROUTES proposes the "Development of guidance for the implementation of deep borehole disposal, including their safety case development" (KM-3) aiming to create a guidance for developing a safety case for deep borehole disposal, that should incorporate the requirements for a safety case development, emphasizing comparisons with other options, and to address specific issues related to deep borehole disposal, including waste emplacement, packaging, safety barriers, and safety related aspects. This guidance is expected to enhance the technical know-how of the deep borehole disposal solution, exploring brand-new possibilities for SIMS by optimizing the routes of RWM to tailor specific requirements and develop sustainable governance solutions. Additionally, it would foster knowledge management sharing between diverse actors.

Long-term storage is also a key element in RWM practices, particularly in less advanced programs dealing with high level waste and spent fuel, but also in most advanced programs that should deal with the cooling of important amount of spent fuel over decades. Its adoption poses socio-technical challenges spanning various aspects of waste management, with public interaction and legal compliance playing crucial roles. The safety case associated with long-term storage adds complexity, often not fully understood by all stakeholders. Despite these challenges, fostering a comprehensive understanding of the socio-technical subtleties is crucial for developing effective and sustainable solutions. ROUTES work enabled to propose the "Identification of social and technical interrelated challenges related to long-term storage" (StSt-8) recommendation aiming to clarify the social and technical dynamics of long-term storage facilities and their

link to final disposal. The recommendation seeks a comprehensive understanding of safety and risk management, intending to provide robust strategies to mitigate potential hazards. Additionally, it aims to optimize storage solutions by aligning with societal and technical requirements, fostering efficiency and sustainable waste management. Engaging both social and technical aspects would encourage constructive dialogues, shared decision-making, stakeholder exchanges (including civil society), and contribute to knowledge management for diverse actors.

### **Development of WAC**

Established WAC or equivalent systems for both pre-disposal and disposal stages are crucial in defining a comprehensive waste management strategy; they serve as an important requirement for ensuring the effectiveness of a waste management route by defining the criteria radioactive waste must comply with, when foreseen for final disposal. However, WAC are still absent or immature for some stages in the waste lifecycle, particularly disposal end points [8]. Work carried out in the frame of ROUTES recognized that an accurate characterization of waste when generated is fundamental. This early characterization not only minimizes downstream challenges but also lays the groundwork for effective waste management throughout its lifecycle. The identification of specific radionuclides and their standardized speciation would allow for a more comprehensive understanding of the nature of radioactive waste, providing a basis for precise treatment strategies and disposal considerations. Moreover, the intricate interplay between stakeholders, including waste producers, treatment and conditioning facility operators, and civil society is a strong argument for the involvement of these stakeholders at an early stage of WAC definition. This engagement fosters a collaborative approach, ensuring that WAC development is practical, effective, and aligned with the safety assessments of facilities. To address these challenges, two ROUTES StSt recommendations have been proposed:

- The “Comparison and standardization of radionuclides (and their speciation) to account for in waste characterization and WAC” (StSt-9) recommendation would aim at responding to the interest of standardizing and thus optimizing the extent of radiological characterization, by providing lists of standardized radionuclide recommendations to account for in characterization and WAC. This recommendation would enable to enhance confidence in the waste characterization completeness, partial harmonization of the set of nuclides for characterization, and improved overall understanding of radiological characterization of wastes, elucidating reasons for variations in the sets of characterized nuclides across countries.
- The “Benchmarking Exercise for WAC Development” (StSt-10) recommendation aims at testing cases of WAC development in order to improve the harmonization and confidence of WAC development methodologies across MS, where SIMS could benefit from the knowledge and experience of LIMS and provide better insight into WAC development.

### **Characterization**

Several member states face a significant challenge in dealing with legacy wastes, primarily due to uncertainties related to their inventory and origin, often as a result of a lack or loss of historical documents. These uncertainties extend to the anticipated behavior of the wastes once retrieved for subsequent management. The key to addressing this challenge lies in the supplementary characterization of these legacy wastes. However, implementing such characterization can be difficult for various reasons, including limited accessibility within legacy storage facilities and variations across the stored waste. ROUTES has identified two so-called “vicious circles” that contribute to the complexities associated with characterizing legacy

wastes, underscoring the pivotal role of identification of characterization issues as the primary reason for considering wastes challenging to manage [7]. On one hand, the lack of adequate characterization hinders the identification of a suitable management route. Conversely, the absence of a defined management route can impede the prioritization of waste characterization, particularly in preparation for retrieval and management. Furthermore, a common dilemma arises where the retrieval of waste from a legacy facility is necessary for adequate characterization. However, ensuring the safe retrieval of this waste requires a prior understanding of its characteristics. This interdependence underscores the need for a comprehensive and integrated approach to address the challenges associated with legacy waste management. Several approaches have been identified to address the characterization challenge, including characterization campaigns examining material sampled at different depths, historical records examination, and requirements to recondition drums containing corroded waste offer the chance for further sampling and characterization. There exists a necessity to enhance characterization methods.

In addition to this, ROUTES' work helped identifying knowledge gaps in characterization of other waste forms [9]. For graphite waste, unresolved issues include defining a Wigner energy threshold for safe disposal and enhancing scaling factors' validation. Characterizing large sludge amounts highlighted the need of methodologies for non-equilibrium radionuclides, improved gamma-spectrometry correction factors, and techniques for re-characterizing solidified SIERS. Moreover, U/Ra/Th-bearing wastes pose challenges in gamma-spectrometry correction factors and representative sampling. Finally, decommissioning wastes present hurdles in representative sampling, in-situ measurements, and scaling factor validation.

To address the challenges described, several ROUTES recommendations have been proposed:

- The “Characterization Methods to Determine Compliance of Particular Wastes with WAC” (R&D-2) recommendation comes from the necessary enhanced waste characterization that would facilitate a comprehensive determination of compliance with WAC, in turn to foster increased confidence in waste characteristics. The recommendation would provide “ready-to-use” solutions to characterize challenging wastes enabling an enhanced comprehension of wastes chemical characterization, an increased potential for the sharing of waste management (characterization) systems, and a greater appreciation of waste compliance with WAC. It is worth noting that mobile (shared) systems for waste package characterization are of particular interest for several European countries.
- The “Research on Wigner Energy Threshold for WAC” (R&D-3) recommendation comes from the challenge associated with graphite waste, characterized by the energy stored within, known as Wigner energy. The challenge lies in the absence of a defined Wigner energy threshold for the final disposal of graphite, a critical parameter that needs to be defined in WAC. Implementing this recommendation would facilitate the development of an up-to-date WAC for graphite, coupled with a safety assessment for final disposal sites incorporating graphite. This, in turn, would enhance the operational and long-term safety of disposal facilities.
- The “Investigate Characterization Methodologies and Identification Techniques For DSRS and Orphan Sources” (R&D-4) recommendation emerges in response to the significant challenges encounter by member states in characterizing and disposing of these sources. The difficulties arise from the diverse and often unknown radiological and chemical inventories, and the long-term storage of these sources without characterization or separation from other waste. This recommendation would allow achieving precise radiological and chemical inventories to effectively define treatment and

conditioning processes, ultimately enabling the anticipation of suitable final disposal for characterized DSRS.

- The “Development of Methodology for Representative Sampling of Challenging Waste Types” (R&D-5) recommendation result from the dependability of characterization results using destructive methods strongly dependent on the representativeness of the samples, particularly for “challenging” waste streams associated with “legacy” facilities; it is therefore crucial for sampling strategies to accommodate the variability within waste streams to ensure thorough identification. The development of a methodology would allow national and international comparison of waste characterization results due to identical, repeatable, and reliable sampling and reduce uncertainties on one hand. On another hand, the recommendation would provide new characterization strategies for heterogeneous waste streams and a higher reliability of characterization results for challenging waste.
- The “Development of Innovative Non-Destructive Methods” (R&D-6) recommendation comes from the need to establish a methodology for non-destructive measurements, with minimal uncertainty, to provide a precise estimation of the activity in the waste packages. It would improve the sorting and minimizing waste from decommissioning due to the possibility to clear larger amounts of material from decommissioning and it would increase the measurement reliability and the determination of scaling factors by addressing the challenges within radioanalytical characterization, specifically the difficult-to-measure radionuclides (SIERs). The recommendation is expected to provide a better sorting of waste from decommissioning as well as a reduced waste due to better determination of decontamination and clearance procedures exemption of materials from decommissioning. The recommendation would enable a more accurate radionuclides inventory determination and a greater reliability of scaling factors.
- The “Development of Innovative Methods for Scaling Factors Validation” (R&D-7) recommendation comes from the dependency of the scaling factor methodology, applied method for the determination of difficult-to-measure radionuclides, on the application of validated scaling factors. The recommendation aims to enhance the reliability of characterization results by improving the reliability of scaling factors.

### **Treatment and Conditioning**

Challenges arise in managing waste like SIERs, sludges, organic waste, or waste containing reactive metals, especially concerning their long-term behavior in disposal conditions. Several member states have explored innovative matrices combined with various treatment processes to stabilize such complex waste. However, the long-term behavior of these matrices in disposal conditions remains unknown, necessitating further exploration before contemplating large-scale development. To answer this challenge, ROUTES identified the recommendation “Explore Long-Term Behavior of Innovative Matrices” (R&D-8) to better understand the degradation mechanisms of innovative matrices in disposal conditions, anticipate potential interactions with disposal components and collect valuable inputs to define WAC associated with these innovative waste packages.

Finally, bituminized wastes are used to condition spent resins and effluent sludges, as being reactive waste, since the 1960s, presenting challenges in its waste lifecycle management for MS. While various R&D programs are addressing these issues, a specific concern is the impact of salts on the long-term evolution of drums containing bituminized waste from reprocessing. As a potential research focus, efforts could aim at implementing treatment processes to eliminate specific chemical species and ensure the production of stable waste packages. However, the treatment is country and safety authority dependent, requiring further investigation at a European level. To answer this challenge, ROUTES identified the recommendation

“Investigate Particular Needs on Treatment Processes for Bituminized Wastes coming from Reprocessing” (R&D-9) to identify the needs and expectations of interested MS in terms of treatment processes for bituminized wastes, obtain an overview of national context and strategy on the subject and possibly define the framework for a future common research program.

## **CONCLUSION**

The ROUTES WP has made substantial contributions in addressing radioactive waste challenges in Europe. It has provided a comprehensive understanding of predisposal issues at the European level, facilitating knowledge and technology sharing. It empowered underrepresented voices to tackle their challenges, engaged civil society representatives, and fostered valuable connections between SIMS and LIMS. The project identified potential stakeholders and customers addressing similar waste-related challenges and innovative treatment approaches. Furthermore, the initiatives have increased visibility on critical topics, such as shared solutions, offering opportunities for partnerships with resource-limited countries. These collaborations aim to promote global cooperation in addressing radioactive waste disposal effectively. Finally, the ROUTES WP enabled the identification of not less than twenty-two recommendations on R&D, StSt and KM activities for future European collaboration; some of these recommendations will be pursued in the next phase of EURAD.

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