EURAD-2 WP description Template #2

Please see Instructions for Work Package Preparation Team, public document for guidance (available on EURAD and PREDIS websites)

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Short Acronym and full Title	**InCoManD In**novative and new **Co**ntainer/canister materials under disposal field conditions: **Man**ufacturing feasibility and improved **D**urability.		
Type of activity	☒R&D	☐Strategic Study	Knowledge Management – covered by a separate committee and template
Budget estimation (total budget in M€)	5 M€	Duration of the WP 60 months	
Links with EURAD SRA / Roadmap Themes (if multiple choices, indicate the primary link **in bold – maximum 3**)	☐Programme Management (Theme 1) ☐Pre-disposal (Theme 2) ☒Engineered Barrier Systems (Theme 3) ☐Geoscience (Theme 4) ☒**Disposal facility design and optimisation (Theme 5)** ☐Siting and Licensing (Theme 6) ☒Safety Case (Theme 7)		
Links with EURAD SRA topics (if multiple choices, indicate the primary link **in bold – maximum 3)**	- 3.2.1 HLW and SF containers **- 3.2.3 Novel containers** - 3.4.1 EBS system		
SRA drivers (maximum 3)	☐Implementation Safety	☒Tailored Solutions	☒Scientific Insight
	☒Innovation for Optimisation	☐Societal Engagement	☐Knowledge Management

Objective (What) – **1 sentence**	The WP advances the state of the art for HLW container/canister materials and their advanced manufacturing technologies and increases the fundamental scientific understanding of such components for performance assessment under long-term deep geological disposal conditions.
Justification: impact / innovation / added-value (Why) – bullet points or short paragraph **(maximum quarter of a page)**	Hereafter, 'container/canister' is frequently referred to as 'component'. Deep geological disposal of high-level waste will subject the canister for various challenges, such as corrosion under anoxic conditions that may lead to, for example, H_2(g) production and compromised material properties. In order to prevent and/or minimize these challenges and to ensure even safer disposal, materials not prone to corrosion can be selected or protecting coatings can be applied to prevent corrosion. In the framework of the EURAD/ConCorD WP, tasks are dedicated to address these topics and already provided promising results, for example on sealing processes of ceramics bodies and PVD methods to deposit protective coatings. HLW container/canister lifetimes are typically calculated based on the time-dependent corrosion behaviour alone, with the implicit assumption that the component has been designed to remain structurally stable indefinitely. However, for some component materials and designs, there may be significant interactions between mechanical and corrosion degradation modes that could affect the ultimate failure time. Even though the durability of several component materials subjected to corrosion processes have been previously studied in detail, the interaction of mechanical processes and corrosion calls for further study, and assessment of the impact of joint degradation modes on component lifetimes will result in a more robust and defensible safety case. Besides, as corrosion occurs in a thin interfacial surface layer between the component outermost surface and the environment, specific R&D work to understand the long-term performance controlled by both the host rock (water saturation, chemistry, microbes) and the disposal system (stress load, materials, temperature, radiation, chemistry) is required.

List of planned tasks / subtasks with % of effort per task (5% increments)
 	
(Maximum 10 bullets)
	• Task 1 (10%): Management/coordination of the WP
	• Task 2 (10%): Knowledge Management (incl. training materials development and State-of-the-Art for R&D WPs, etc.)
	  o Workshops, State-of-the-art report at the start, update in the middle, and final version at the end of the project, data management, summer school for young researchers…
	• Task 3 (~20%): (i) Identification of innovative HLW container materials or coatings, which includes ceramics, metals, and composites of those; improvement of recently defined alternative solutions; (ii) Development of dedicated production routes: elaboration processes for both metallic, ceramic, and composite coatings and (large) bulk pieces, including their sealing
	  o In this part, it will be used a panel of elaboration processes (e.g. PVD and cold/thermal spray techniques, sol-gel method) and characterization techniques (e.g. XRD, SEM, X-ray tomography, ICP-MS, Raman), coupled with modelling methods (e.g. FEM, MD).

	• Task 4 (~20%): (i) Evaluation of *in situ* durability of materials identified by task 3 at laboratory scale and beyond and identification of the main processes and transients of interest. These transients include, for example, degradation of engineered barrier, intrusion of pore water from the surrounding host rock, gas generation, aerobic/anaerobic atmosphere, ambient/high temperature, unsaturated/saturated conditions, non-irradiating/irradiating environment, and the presence or absence of microbial activity; (ii) Development of *ad hoc* experiments to mimic accelerated field conditions (pH, temperature, irradiation…) • Task 5 (~20%): For innovative or established materials of interest identified by task 3, (i) assessment of the extent of joint mechanical-corrosion degradation modes and, (ii) measure of threshold stresses and stress intensity factors as a function of material properties and comparison of threshold conditions with levels of tensile stress under repository conditions, considering the possible role of defects. Mock up experiments will be tailored to understand the processes that would occur under final disposal conditions. A combination of characterization tools associated with geochemical modelling will be employed to determine the corrosion mechanisms and the associated corrosion rates. • Task 6 (~15%): Development of modelling approaches related to the outcomes of tasks 3, 4, 5 to describe the influence of the physico-chemical, time-dependent transformations that are prone to impact the formation and hypothetical transformation (conversion) of corrosion products and their associated passivating properties; (ii) Development of modelling capabilities capable of capturing the main coupled interfacial processes influencing components long-term performance under deep geological disposal relevant conditions for the purpose of performance assessment. • Task 7 (~5 %): Preliminary considerations about the LCC/LCA (Life cycle costing/assessment) approaches, the availability of the raw materials, as well as of the impact of improved or new solutions on cell materials.
List of expected outcomes linked to the identified SRA drivers **(Maximum 6 bullets)**	The increased understanding will contribute the following SRA drivers: • Implementation of safety: the increased understanding on canister behaviour will increase the confidence of life assessment and ensures long-term safety. • Tailored Solutions: The WP will address HLW disposal challenges across the Europe from scientific and economic point of views. It is foreseen that significant added value can be obtained when the work on metallic and ceramic materials are examined in the same WP and towards the common goal. • Scientific insight: Joint and simultaneously operating degradation mechanisms are demanding to tackle scientifically. It is foreseen that clarifying these mechanisms within the WP will have a significant impact on pushing the state-of-the-art beyond the current state.

	• Innovation and optimization: The final disposal of HLW is in very different phase across the Europe, but even in the most advanced countries, improvements of current reference solutions are intensely investigated. In addition, upon starting the mass-production of canisters, those improved solutions must be financially reasonable, material supply chains must be reliable and appropriate fabrication technologies must be available. The proposed LCC/LCA analyses make the first effort to capture the economic and technical aspects of advanced HLW canister solutions. • Social Engagement: Advancing the canister solutions is a clear sign to the stakeholders and society that the scientific community is continuously working hard for ensuring the best safety conditions of the final disposal. • Knowledge management: The proposed WP will make a significant effort in training new scientists, in reporting the state-of-the-art in such a form that it is easily accessible, and to disseminate the results both through peer-reviewed papers and during lectures at the Master and Doctorate levels.
Deliverables **(Maximum 6 – including the prescribed deliverables)**	• SotA report initial • Report on advanced and novel canister materials and fabrication routes including LCC/LCA (Life cycle costing/assessment) on considered canister solutions (tasks 3 and 7) • Report on main degradation modes (mechanical + corrosion) for several canister options and modelling approaches for capturing the canister degradation modes (tasks 4, 5, 6) • SotA report final • Outcome/impacts report to Member States and End Users
Critical input requirements & identified risks	• Qualitative and quantitative output of the ConCorD WP regarding pre-selection of new materials for additional protection (coating) of the containers.
Major achievements expected by end of Year 2 (Go/No Assessment)[1] **(Maximum 5 bullets)**	• Identification of state-of the-art solutions that include the bulk and coating, metallic and ceramic materials for the container but also fabrication routes - GO: small-size (typically 1/4th scale) fabrication tests; No GO: additional screening tests • Successful (*i.e.*, mechanical and corrosion resistance) sealing of a ceramic container using the microwave heating that is currently the most advanced method; this requires improvement of both the sealing material and the heating process • A clarified set of threshold conditions for at least one canister material under repository conditions which can be experimentally verified, and which mechanisms are well understood taking into account possible defects.

[1] EC budget being only allocated for the first 2 years, each work package progress will be reviewed at the end of Year 2, to assess its continuation based on the total budget that EURAD-2 will be granted.

(Optional - Explain what is out of the scope?)	---
List of preliminary interested organisations as partners in the WP contributing effort; **% of effort (person months, by College)**	Identified interested organisations *(no information so far regarding their potential involvement)*: REs (appr. 60%): CNRS-IRCER/France ; CNRS-subatech/France ; CIEMAT/Spain ; ÚJV Řež/Czech Republic ; BAM/Germany ; Jacobs/UK ; HZDR/Germany ; SCK CEN/Belgique ; brgm/France ; NSC KIPT/Ukraine ; UPM/Spain ; PSI/Switzerland ; Univ Bern/Switzerland ; CEA/France ; ZAG/Slovenia; EDF/France ; ÚJV Řež/CheckRep. ; UniMAN/UK ; KIT-INE/Germany ; EPFL/Switzerland ; Univ. Warsaw/Poland ; Tractebel/Belgium TSOs (appr. 15%): VTT/ Finland ; SSM/Sweden ; BASE/Germany ; NRG/Netherlands ; IRSN/France WMOs (appr. 25%): Andra/France, Posiva/Finland ; Nagra/Switzerland ; ONDRAF/Belgium ; Enresa/Spain ; SKB/Sweden ; NWS/UK ; *(KORAD/Korea)*
If applicable - links with previous projects / work packages	EURAD/ ConCorD EURAD/ ACED
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