Short Acronym and full Title	**ANCHORS** -hydr**A**ulic mecha**N**ical **CH**emical evolution of bent**O**nite for barrie**R**s optimi**S**ation		
Type of activity	☒R&D	☐Strategic Study	Knowledge Management – covered by a separate committee and template
Budget estimation (total budget in M€, i.e ~ 1.5 M€)	8 M€	Duration of the WP (in months)	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)	- 3.3.1 - **Characterised bentonite / clay-based material evolution under specific conditions to provide data on hydro-mechanical, thermal, gas transfer and chemical behaviour**. - 3.3.2 – Improved understanding of mixtures bentonite/crushed rock, bentonite/sand, sand/crushed rock - 3.3.3 Improved understanding of the performance of plugs and seals		
SRA drivers **(maximum 3)**	☒Implementation Safety	☐Tailored Solutions	☒Scientific Insight
	☒Innovation for Optimisation	☐Societal Engagement	☐Knowledge Management
Objective (What) – **1 sentence**	The objective of this WP is to increase the optimisation potential of bentonite barrier systems: buffer, backfill and seals, and the Safety Case resilience 1) by qualifying the HM behaviour of various kind of bentonite types and mixtures through laboratory experimental programme focused on **heterogeneity** and **chemical effects** at different scales and 2) by improving the numerical tools that are necessary to carry out performance assessment of bentonite barriers in a THMCG repository environment.		
Justification: impact / innovation /	The safety of Deep Geological Repositories (DGR) relies in the early phase after closure of the repository mainly on engineered barrier systems (EBS). In most repository concepts, bentonite is used as the principal geomaterial sealing		

added-value (Why) – bullet points or short paragraph **(maximum quarter of a page)**	element in these systems. Thus, the knowledge of long-term THMCG behaviour of bentonite-based components contributes, as a main factor, to safety improvement, design, and optimisation of the EBS, for all deep geological repository concepts. Whereas several bentonites are well studied, and their sealing and retention properties have been investigated, a rising number of alternative bentonites and bentonite-based mixtures are under consideration across Europe that are not well investigated yet. Potential disruptions to the global bentonite supply chain (e.g., geopolitical issues, costs etc.) could severely restrict the supply of the well-studied bentonite. To mitigate this problem, a wide range of alternative bentonites and bentonite-based materials need to be characterised for use in the sealing of DGR without compromising its safety. The objective of the proposed work package is to: • Investigate chemical effects (e.g., alkaline and saline conditions) on the HM behavior of bentonite and bentonite-based mixtures. • Get insights into the effect of water chemistry on gas migration processes in bentonite and bentonite mixtures. • Study the consequence of bentonite and bentonite mixtures heterogeneities in long term sealing performance under repository boundary conditions. • Improve THMCG constitutive models related to the micro/macro interactions of the bentonite structure and the heterogeneity. • Investigate the effect of scale on bentonite testing. Additionally, this work package involves the establishment of a comprehensive database containing THMCG material properties and representative numerical results for various kinds of bentonites and bentonite mixtures. These efforts ultimately contribute to the optimisation of Deep Geological Repository (DGR) designs.
List of planned tasks / subtasks with % of effort per task (5% increments) **(Maximum 10 bullets)**	• **Task 1: Management/coordination of the WP, 10%.** • **Task 2: Knowledge Management, 15%.** - Knowledge Management (incl. training materials development and State-of-the-Art for R&D WPs, etc.), - Development of a database on the characterisation, THMCG behaviour of different kind of bentonite types and mixtures based on the compilation of previous small- and large-scale experiments and from new experiments to be carry out in EURAD-2. - Assessment of measures for better quality control and testing of bentonite. • **Task 3: Lab testing, Multiscale experimental characterization of a wide range of bentonite types (**e.g., Na and Ca bentonites from different locations) **and bentonite-based mixtures**. Specific focus on chemical loadings, heterogeneity, components proportion, components characterization, role of friction in link with scale effects and mixture optimisation (influence of variations in the bentonite-based mixture components), laboratory characterization of “aged or matured” bentonite/mixtures coming from “in situ” tests or mock-up tests (if samples are available), **40%.** o **Subtask 3.1 Micro scale testing/characterization.** In-depth microstructural characterization of different kind of bentonite types and bentonite-based mixtures. Complementary techniques

	including non-destructive methods and direct observations of the processes during the tests, 20%. o **Subtask 3.2 HMCG Laboratory testing/characterization.** small scale tests (centimetric) and mock-ups (decimetric) on alternative bentonite and bentonite mixtures to improve understanding of the micro-scale mechanism. Experimental benchmarking, 20%. ● **Task 4: Bentonite Barrier modelling and Performance assessment, 30%.** o **Subtask 4.1: Enhancement of existing constitutive models and numerical tools** including coupling with temperature and relevant chemistry, gas flow. Micro/macros coupling in link with Task 3, consideration of heterogeneity and transient behavior. Validation and calibration of the improved constitutive models and numerical tools: extensive modelling of small scales and mock-up experiments and upscaling to in situ experiments, 15%. o **Subtask 4.2: Application to assessment cases**: Enhance confidence in numerical tools for safety case applications by focusing on large-scale bentonite barriers components. This includes investigating the sensitivity of parameters in the long-term evolution of bentonite barriers, 15%. ● **Task 5 Social engagement, 5%.**
List of expected outcomes linked to the identified SRA drivers **(Maximum 6 bullets)**	• Innovation for Optimisation: Study of crushed pellets and mixtures of bentonite with crushed rock or coarse-grained soils, linked to WP 13, including the development of non-destructive tests, and carrying out mock-up tests. Performing the characterization of different types of bentonites to assure a safe supply chain, (SRA 3.3.2). • Tailored Solutions: Tailoring bentonite components and seal designs for different system requirements or for the optimisation of existing concepts (linked to WP 13). Chemical effects due to the interaction between the bentonite and different components required for the construction of tunnels and caverns like cement and steel or components of the canister like cast iron, (linked to WP 11) (SRA 3.3.3). • Knowledge management: Create a database with the experimental results dispersed in different reports and articles, adding the tests results obtained in this project, (SRA 3.3.1). • Scientific Insight: The improvement of the THMCG constitutive models (linked to WP 18) related to the interaction micro/macros of the bentonite structure and the heterogeneity, followed by the implementation of these improvements in computer codes will enhance the understanding of more complex systems at laboratory scales, and lead to improve scientific insight on key controls, (SRA 3.3.1). • Implementation Safety: The post closure environmental safety case (linked to WP 7 and 19) requires improving the current numerical tools, considering the coupling THMCG coupled processes that start when the canisters are emplaced. The computer codes that are going to be used in THMCG simulations should be validated and verified. The modelling benchmarking comparing different codes, and the development of analytical and semi-analytical solutions is going to ensure long-term safety. The laboratory benchmarking will provide accepted tests for improving the quality validations, (SRA 3.3.1).

Deliverables **(Maximum 6 – including the prescribed deliverables)**	• Outcome/impacts report to Member States and End Users, collection of at least five peer reviewed papers. • State-of-the-Art report (initial and final) and data base. • Report on Lab testing and multiscale experimental characterization results. • Report on modelling enhancement and validation. • Report on assessment cases. • Report on social engagement.
Critical input requirements & identified risks	• The information for preparing the database is dispersed and part could be only in paper form. The NWOs, as mainly owners of the non-public information, could not provide this information. • THMCG simulations are complex and there could be numerical issues that could make difficulties for carrying out simulations. • Delay in the experimental data for further improvement of the constitutive models. • Bentonites are raw materials and the differences in results could be due to the variability of the material supplied. • Tests in bentonites are slow and part of them could not be finished at the end of EURAD-2.
Major achievements expected by end of Year 2 (Go/No Assessment)[1] **(Maximum 5 bullets)**	• Database ready. Assessment of the differences between tests carried out in similar conditions and the apparent differences between the results obtained in small-scale samples and in mock-up and “in situ” tests. • Definition of the tests to be carried out during the second step, including the election of the bentonites that are going to be tested and the non-destructive tests. • Formulation and definition of the THMCG models to be used in the simulations as well as initial validation of these models by targeting specific key processes. • Experimental inputs for further improvement of constitutive model during the next three years of the project. • Documentation of the first results on performance assessment of bentonite EBS.
(Optional - Explain what is out of the scope?)	- The preparation of standards or rules to be used by NWOs or authorities. - The characterization of bentonite will not be carried out for commercial issues. - Full-scale simulations of the repositories.

[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.

List of preliminary interested organisations as partners in the WP contributing effort; **% of effort (person months, by College)**	REs (55%): Confirmed: EK/HU, PSI/CH, CNRS-NAVIER/FR, UGN-CAS/CZ, JYU/FI, Mitta/FI, CVUT/CZ, UJV/CZ, CT/SE, UPC/ES, UCLM/ES, EPFL/CH, GTK/FI, UH/FI, LP2i/FR, UDC/ES, TUBAF/DE, BRGM/FR, NTW/FR, LEI/LT, ETH GEG/CH, EDF/FR, ULIEGE/BE, TUDELFT/NL, CEA/FR, UL/FR, UMU/SE, LR/FR, JRC/GE, CU/SE (30 organizations) Confirmation pending: BGS/UK, UAM/ES, UoM/UK, CSIC-IETcc/ES, UPM/ES, TUL/CZ, UGR/ES, EDIN/UK, ICL/UK, INGPAN/PO, NCSRD/GR, CU/CZ, HZDR/DE, SUBATECH/FR, OU/UK, SCK-CEN/BE, ZAG/HR, UFZ/DE, TU BS/DE (19 organizations) TSOs (30%): IRSN/FR, CIEMAT/ES, VTT/FI, GRS/DE, SSM/SE, EIMV/SL, GI-BAS/BU, CEPN/FR, BGR/DE (9 organizations) WMOs (15%): ENRESA/ES, ANDRA/FR, Posiva/FI, Nagra/CH, BGE/DE, PURAM/HU, SURAO/CZ, NWS/UK, SKB/SE (9 organizations) Total: 67 organisations This is a preliminary list of groups who have so far expressed interest in ANCHORS. We do not consider this list closed nor any preselection for a potential future involvement in ANCHORS. The % Effort per college type is a rough estimation at this stage.
If applicable - links with previous projects / work packages	DOPAS, MODATS, BEACON, HITEC, BELBaR, ABM, LOT, FEBEX, PEBS, GAS, FORGE
WP Preparation Team (1 member per College) contact (**organisation + person**, email)	RE: Mitta Oy; Xavier Pintado; xavier.pintado@mitta.fi TSO: IRSN; Nadia Mokni; nadia.mokni@irsn.fr WMO: BGE; Eric Simo; eric.simo@bge.de CG observer: VTT; Erika Holt; erika.holt@vtt.fi