EURAD-2 WP21 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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<table>
<tr><td>Short Acronym and full Title</td><td colspan="3">NATAN – Natural analogues and long-term evolution: upscaling towards relevant space and time scales</td></tr>
<tr><td>Type of activity</td><td>☒R&D</td><td>☐Strategic Study</td><td>Knowledge Management – covered by a separate committee and template</td></tr>
<tr><td>Budget estimation (total budget in M€, i.e ~ 1.5 M€)</td><td>5 M€ (including personnel costs & NA site characterisation)</td><td>Duration of the WP
(in months)</td><td>60</td></tr>
<tr><td>Links with EURAD SRA / Roadmap Themes
(if multiple choices, indicate the primary link in bold – maximum 3)</td><td colspan="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)</td></tr>
<tr><td>Links with EURAD SRA topics
(if multiple choices, indicate the primary link in bold – maximum 3)</td><td colspan="3">3.4.1 EBS system
4.3.1 Geological and tectonic evolution
7.1.2. Performance indicators: shared experience in the use of natural analogues</td></tr>
<tr><td rowspan="2">SRA drivers (maximum 3)</td><td>☒Implementation Safety</td><td>☐Tailored Solutions</td><td>☒Scientific Insight</td></tr>
<tr><td>☐Innovation for Optimisation</td><td>☒Societal Engagement</td><td>☐Knowledge Management</td></tr>
<tr><td>Objective (What) – 1 sentence</td><td colspan="3">Using natural analogues (NA) to upscale laboratory based, URL-derived and instrumental data in space and time, to test future scenarios of long-term</td></tr>
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	evolution, and to build confidence in and provide supporting arguments to the safety case.
Justification: impact / innovation / added-value (Why) – bullet points or short paragraph **(maximum quarter of a page)**	NA are relevant for many aspects of waste disposal programmes and are crucial to understand long-term processes, and to test whether experimentally derived data (e.g. rates) at different space and time scales and process predictions are consistent with natural records. NA are an inherent part of the multiple lines of reasoning strategy for building or optimising the safety case in different disposal concepts. Moreover, NA will advance the state-of-the-art knowledge of geosphere and engineered barrier system processes and concepts relevant for radioactive waste management programmes. NA came gradually into the picture of waste disposal programmes with founding the Natural Analogues Working Group (NAWG) in 1985 (www.natural-analogues.com). Since then, 17 NAWG workshops have been organised and many different analogues presented, mainly on radionuclide migration studies. The initial use of NA focused on process understanding and model/database validation, whereas additional opportunities in public communication and training of new generations have received less attention. Since each analogue is often very specific for a group of FEP's, there is a clear need to expand the range of useful analogues for future NA catalogues. NA catalogues have been recently updated which have identified activities to be undertaken in the immediate future, emphasising the potential use of regional (or self) analogues for the benefit of the different participating countries, normally not done in the past (https://doi.org/10.5194/egusphere-egu22-9127). The proposed WP will build knowledge beyond existing work by including i) novel, less studied FEP's (related to, e.g., clay-metal interface, validation of permafrost and geodynamic models) and ii) novel (self)-sites (e.g., North Sea Basin, clay-rich outcrops). There is also a continuing need for scientific investigations of existing sites (e.g., Kiruna, studying clay/metal interfaces) as some are poorly characterised while still representing unique characteristics directly relevant to radioactive waste disposal. Furthermore, state of the art analytical/spectroscopic techniques (e.g., AMS, HR-ICP-MS, synchrotron) with very low detection limits (e.g., U-236) and novel remotely sensed data (e.g., satellite data from EGMS) generate information with higher precision that can further reduce uncertainties in the safety case. Civil society (ICS) experts will participate to a pluralistic dialogue to allow a better common understanding (between experts and civil society) about the meaning of the link between NA studies and safety case. These exchanges lead to feedback on governance aspects of socio-technical challenges to be transferred to future generations. Finally, while there are natural synergies with other WPs (#11 , #14 (StS), #15 and #16) which will be leveraged, the benefit of this WP is the singular focus on using NA to bring an integrated view of the insight they provide for future repositories. Moreover, the specific approach of NA studies including field exploration and sampling, makes this WP to be treated as a separate topic. Thus, while investigating separate sites and different processes, the effort will focus on integrating information from previous work (from the SotA) and the findings in this WP in a comprehensive view, with the clear aim of supporting national programmes.
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 (incl. training materials development, State-of-the-Art for R&D, ICS), 10%. • Task 3: Permafrost and geodynamics, 25 % (possible link with WP14 Climate change – StS).

	○ Subtask 3.1: Development of a set of robust and generic permafrost models that are tested against existing and yet-to-be-extracted/processed verification data (analogues) to assess the spatial distribution (depth and extent) and type of permafrost in the future. ○ Subtask 3.2: Qualification of short-term observations on crustal movement (satellite data) and erosion for future predictions based on long-term NA data (from geological archives). ○ Subtask 3.3: Linking permafrost and geodynamic natural analogues with flow, transport and migration analogues (Task 4). (Possible sites: Palaeogene-Neogene outcrop and subcrop in southern North Sea basin; Fennoscandinavian shield; present-day arctic regions). • Task 4: Flow and transport including radionuclide migration, 25 % (possible link with WP15 Radionuclides and WP16 - ILW) ○ Subtask 4.1: Constraints on flow and transport in host rocks and surrounding aquifers through groundwater dating and tracing of NA study cases in relevant geological settings. ○ Subtask 4.2: Radionuclide migration analogue studies using state-of-the-art analytical techniques (SIMS/nano-SIMS, synchrotron and AMS). Advances in simulation of natural reactor functioning will improve the identification of isotopic "anomalies" and the migration/sequestration processes. (Possible sites: clay-rich Mesozoic outcrop and subcrop in Alpine foreland; northern Apennines; Rupelian outcrop and subcrop in northwestern Europe; Ruprechtov and Oklo sites). • Task 5: Corrosion processes at the clay-metal interface, 30 % (possible link with WP11 Containers/canisters) ○ Subtask 5.1: Constraints on corrosion behaviour of copper under anaerobic conditions and the role of, e.g., sulphide and cracking. ○ Subtask 5.2: Constraints on corrosion behaviour of steel under anaerobic conditions, including cracking. ○ Subtask 5.3: Constraints on microbiological and mineralogical processes at the clay-metal interface. (Possible sites: Kiiruna, SE; Autun, FR; Nydam Mose, DK).
List of expected outcomes linked to the identified SRA drivers **(Maximum 6 bullets)**	The outcomes that are linked to SRA drivers Implementation safety and Scientific insight: • Reduced uncertainties (safety case) by considering repository-relevant timescales and conditions. • Improved knowledge of the interaction between the waste package surface and different barriers in the disposal facility regarding, e.g., corrosion mechanisms and radionuclide migration/ sequestration over long time and spatial scales. • Improved knowledge on flow and transport in host rocks and surrounding aquifers under various (past) conditions.

	• Using NA to assess slow kinetic constraints (metastability). • Improved knowledge of long-term erosion processes crustal movements and permafrost dynamics on a European scale. The outcomes that are linked to SRA driver Societal Engagement: • Supporting and explaining the reasoning strategy within the safety case on a European scale by using NA (e.g., permafrost).
Deliverables **(Maximum 6 – including the prescribed deliverables)**	• D21.1 (Task 2): State-of-the-Art report • D21.2 Outcome/impacts report to Member States (including application to Safety Case) • D21.3 (Task 3) Report of NA studies on permafrost and geodynamics • D21.4 (Task 4) Report of NA studies on flow, transport and radionuclide migration • D21.5 (Task 5) Report of NA studies on corrosion at the clay-metal interface • D21.6 Create EU-NA catalogue database and link with specific FEPs
Critical input requirements & identified risks	• Risk mainly related to timing: if access to field sites is being postponed (meteorological circumstances, etc.) this may have impact on planning. • Critical input data is derived from field work. If sites, for unexpected reasons, become entirely inaccessible, alternative locations will need to be looked for.
Major achievements expected by end of Year 2 (Go/No Assessment)[1] **(Maximum 5 bullets)**	• A1: Field site investigation and descriptions • A2: Sample set description and quality assessment of samples • A3: Set up of relevant databases with existing and new sample and field data • A4: Demonstration of the relevance of NAs in the Safety Case & communication tool
(Optional - Explain what is out of the scope?)	Safety assessment calculations.
List of preliminary interested organisations as partners in the	REs (appr. 75%): SCK CEN/BE (60 pm), CEA/FR (57 pm), BRGM/FR (20 pm), ZAG/SI (40 pm), Uni Bord.-CNRS/FR (25 pm), ENEA/IT (20 pm), Uni Amsterdam (XX pm), MITTA/FI (16 pm), *PSI/CH (36 pm)*, UJV/CZ (XX pm), FEGINLS/FI (30 pm), GTK/FI (25.5 pm), UTU/FI (26 pm), *Uni Bern/CH (60 pm)*, *EPFL/CH (48 pm)*, GFZ/DE (12 pm), TNO/NL (22 pm), Uni Wageningen/NL (48

[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.

WP contributing effort; **% of effort (person months, by College)**	pm), SGU/SE (4 pm), TUDelft/NL (12 pm), Uni Pisa/IT (20 pm), Uni Granada/ES (24 pm), RINA-CSM/IT (XX pm), KIT/DE (XX pm), Uni Rennes-CNRS/FR (XX pm) TSOs (appr. 15%): IRSN/FR (50 pm), GRS/DE (7 pm), NRG/NL (0 pm), SURO/CZ (20 pm), NTW/EU (XX pm), CIEMAT (35 pm) WMOs (appr. 10%): BGE/DE (10 pm), *NAGRA/CH (5 pm)*, *NWS/GB (6 pm)*, SURAO/CZ (XX pm), Posiva/FI (6 pm), SKB/SE (XX pm), COVRA/NL (3 pm), International partners: Integrity Corrosion Consulting Ltd/CA, NUMO/JP.
If applicable - links with previous projects / work packages	**Previous projects**: NA have not been the subject of any R&D EU project so far. Specific NA have been studied in different projects: - Tracers in clay formations: Natural tracer profiles of argillaceous formations in Europe were investigated in the CLAYTRAC project (2009), funded by NEA (https://www.oecd-nea.org/jcms/pl_14268/natural-tracer-profiles-across-argillaceous-formations-the-claytrac-project?details=true). - Bentonite behaviour: KiNa project (2019-2022) IGD-TP project investigates the formations of smectite-rich clay occurring adjacent to magnetite deposits in the Kiruna mine in Sweden as a NA to explore the long-term evolution of bentonite components of a geological disposal system for radioactive waste. (https://igdtp.eu/activity/kina-kiruna-natural-analogue/) - Several fault databases and maps exist for Europe (e.g., H2020- funded seismofaults.eu) but are often not covering an area of interest and/or unverified with recent land movement data. **Consortiums/Networks of interest**: - Natural Analogue Working Group, in the context of radioactive waste disposal (www.natural-analogues.com). Although not a project, this working group share information and offer an international forum for the discussion of NA programmes. In this platform, so far only the topics of bentonite, steel longevity, RN retardation and glacial phenomena are treated. - NANET (2003-2004) - Network to review NA studies and their applications to repository safety assessment and public communication (https://cordis.europa.eu/project/id/FIKW-CT-2002-20204). - CATCHNET Network (2019 – present) (Catchment transport and Cryo-hydrology Network): understanding of hydrological and biogeochemical transport processes for a range of cold-climate conditions in the context of long-term, deep geological disposal of spent nuclear fuel (https://skb.se/catchnet/this-is-catchnet/). Different scope and objectives than the permafrost studies envisaged here.
WP Preparation Team (1 member per College) contact (**organisation + person**, email)	RE: SCK CEN – Vanessa Montoya (vanessa.montoya@sckcen.be); Koen Beerten (koen.beerten@sckcen.be) TSO: IRSN – Alkiviadis Gourgiotis (alkiviadis.gourgiotis@irsn.fr) WMO: BGE – Milena Schoenhofen-Romer (milena.schoenhofen-romer@bge.de) CG observer: EIMV – Nadja Železnik (nadja.zeleznik@eimv.si)