UMAN – A PLURALISTIC VIEW OF UNCERTAINTIES MANAGEMENT

June 2, 2022 •
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The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n° 847593.

OUTLINES

- RATIONALES
- UMAN OBJECTIVES and GENERAL APPROACH
- MUTUAL UNDERSTANDING ABOUT UNCERTAINTY MANAGEMENT
  - ACTORS INVOLVED
  - CLASSIFICATION SCHEMES
  - STRATEGY APPROACH
- APPLICATION OF UMAN METHODOLOGY TO UNCERTAINTIES ASSOCIATED WITH SITE AND GEOSPHERE
  - SIGNIFICANCE FOR SAFETY OF SITE AND GEOSPHERE UNCERTAINTIES
  - FEEDBACK FROM WORKSHOPS AND SEMINARS
- OUTLOOK
- CONCLUSIONS

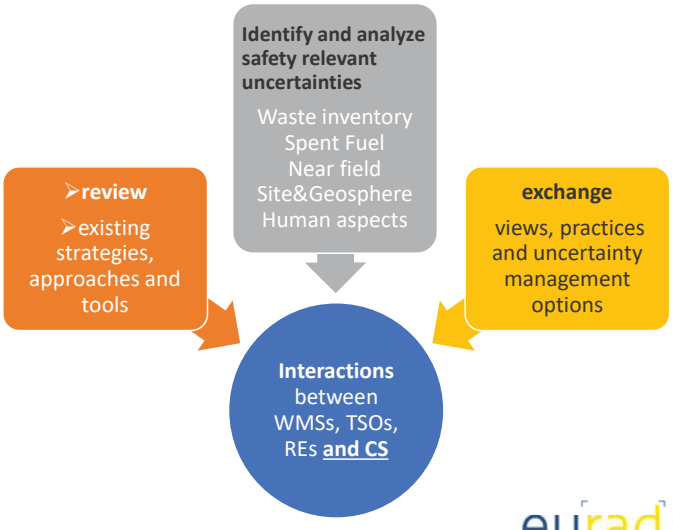
WHY A STRATEGIC STUDY ON UNCERTAINTIES?

- Decisions associated with RWM programmes are made in the presence of irreducible and reducible uncertainties
- early programme phases
  - choices are made on the basis of limited information,
  - must be confirmed before or during construction or operation
- end of the process –
  - uncertainties will inevitably remain
  - demonstrate they do not undermine safety arguments
- along the programme
  - transparency must be provided → effective public information and stakeholders **participation** in the decision-making process
- Uncertainties management of - a key element of successful programme planning and of the safety case of waste management facilities, in particular, of waste disposal facilities due to the long time scales during which the radiotoxicity of the waste remains significant

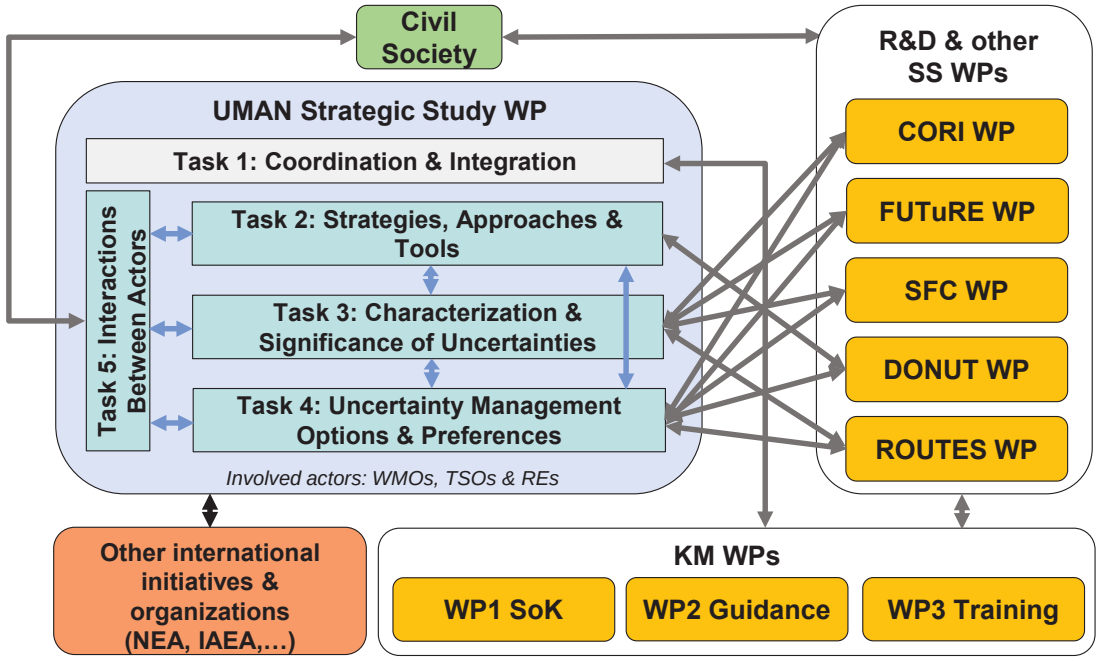
- **Can uncertainty be managed ? If yes, how can it be managed?**

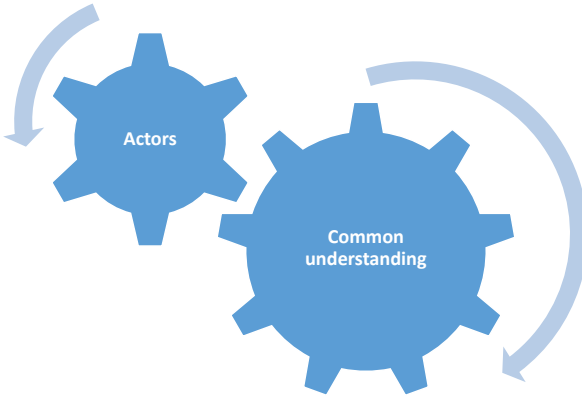
UMAN OBJECTIVES AND APPROACH

- Common understanding on uncertainty management and how it relates to risk & safety among (WMOs, TSOs, REs & Civil Society)
  - If a common understanding is beyond reach → achieve mutual understanding on why views are different
- Create a speace for sharing knowledge/know-how and discuss common methodological / strategical challenging issues
- Identify the contribution of past & on-going R&D projects to the overall management of uncertainties
- Identify remaining and emerging aspects and needs



INTERACTIONS INSIDE AND OUTSIDE EURAD





Reaching mutual understanding

ACTORS INVOLVED IN RWM PROGRAMME

- EURAD survey → 18 categories
  - Contributing actors
  - Other actors
- complex stakeholder system
  - very strong interactions and dependencies
  - Multidisciplinary - organisations and individuals with different technical, political, scientific and societal backgrounds.
- actors' role/engagement
  - depends on national specificity
  - involvement evolves in time

DEFINITIONS FOR A COMMON UNDERSTANDING

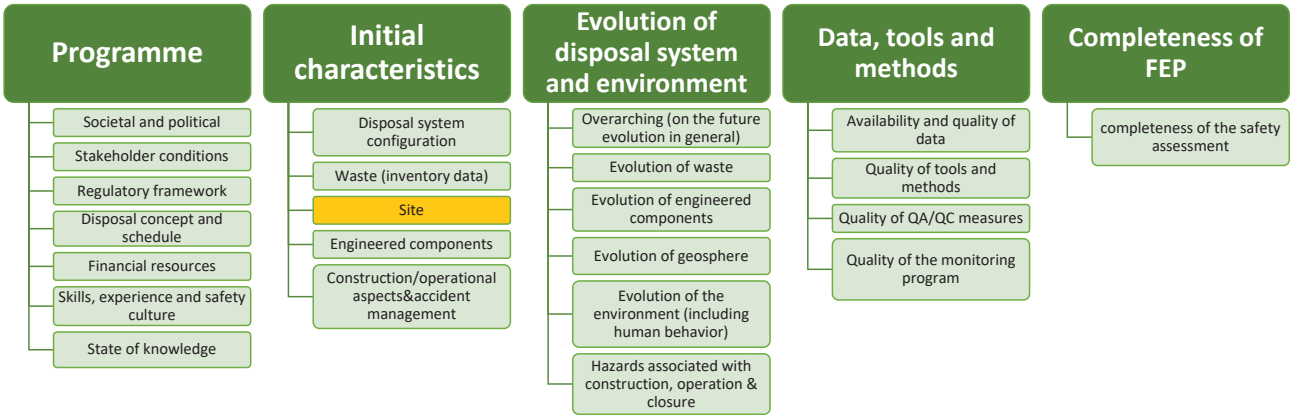
- **Uncertainty**
  - a total or partial lack of **objective** information (evidence) or **subjective** information (knowledge) and is used to express **doubts** about a result (Nagra, 2019)
  - includes also doubts about the validity of concepts, methods, measurements and values.
- **Risk**
  - a quantity expressing hazard, danger or chance of harmful or injurious consequences associated with exposures or potential exposures (IAEA Safety Glossary)
  - relates to a scenario or sequence of events and can be interpreted as the measure of significance of an uncertainty.

Epistemic	Aleatory
Uncertainty on model resulting from limited knowledge of natural conditions and processes (missing parameter, characteristics of model parameter).	- uncertainty that is stochastic for the parameters in a model. - variability of parameter values originates in the random choice of model parameters
can be reduced by adequate research and more information about the natural systems	an intrinsic property of the model parameters and cannot be reduced.

UMAN approach on uncertainties classification

COMMON UNDERSTANDING OF UNCERTAINTIES CLASSIFICATION

1st UMAN Questionnaire → 3 levels uncertainty scheme



THIRD LEVEL

Site

Uncertainties on structural and geometric data of the host rock and surrounding geological layers and aquifers

- Site topography, Depth, dimensions and topography of geological layers, Homogeneity, Geological structures

•Uncertainties on hydraulic conditions and liquid & gas flow in host rock

- Kinematic porosity, Hydraulic conductivity, Hydraulic heads and gradients, Gas flow properties and processes

•Uncertainties on geochemistry and solute transport properties in host rock

- Chemical, radiochemical and mineralogical composition, Groundwater chemistry, Solubility limits, Sorption parameters, Diffusion coefficients, Colloid transport, Changes in the transport properties

Uncertainties on thermal and mechanical properties of the undisturbed host rock

Geo-mechanical properties, Thermal properties, In situ stress field

UNCERTAINTIES CLASSIFICATION BASED ON AVAILABILITY & USE OF KNOWLEDGE

1. **Programme uncertainties**
2. Uncertainties associated with **initial characteristics** of **waste**, **site** and **engineered components**
3. Uncertainties in **evolution of disposal system and its environment**
4. Uncertainties associated with **data, tools and methods** used in the safety case
5. Uncertainties associated with the **completeness of FEPs** (Features, Events & Processes)

Knowledge is available	*Lack of knowledge*
Known Knowns *What is known & used*	**Known Unknowns** *What we know we don't know*
Unknown/Ignored Knowns *What is known but we are not aware of or do not consider*	**Unknown Unknowns** *What we don't know we don't know*

Uncertainties associated with FEP completeness

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WIPP accident

The organic ingredients added as sorbents and neutralizers reacted with the nitrate-salt waste and created gases that increased the pressure in the drum. The materials self-heated and combusted. The combination of the nitrate salt residues, organic sorbent (Swheat Scoop®), and neutralizing agent (TEA) represented a reactive chemical mixture of fuels and oxidizers.

(P.Thakur , B.G. Lemons, and C.R. White - The Magnitude and Relevance of the February 2014 Radiation Release from the Waste Isolation Pilot Plant Repository in New Mexico, USA, 2016)

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Uncertainties associated with FEP completeness

UNCERTAINTY CLASSIFICATION MATRIX

5. Uncertainties associated with FEP completeness

	Known unknowns	Unknown/Ignored Knowns	Unknown Unknowns
1. Programme uncertainties			
2. Uncertainties associated with initial characteristics			
3. Uncertainties in the evolution of the disposal system & its environment			
4. Uncertainties associated with data, tools & methods used in the safety case			

UMAN approach on uncertainties management

Iterative process grouping all activities aimed at identifying, recording, characterizing, classifying, analyzing, treating, assessing, reducing, avoiding and mitigating any type of uncertainties (technical, scientific, social, politic, financial,…).

ELEMENTS OF AN UNCERTAINTY MANAGEMENT STRATEGY

Prevailing circumstances

State of Knowledge	Waste inventory	Available resources	National Policies	Regulatory framework	Stakeholder conditions

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Programmatic activities

Uncertainty identification, characterization & analysis of safety relevance

Return on experience

Uncertainty representation & evaluation in the Safety Assessment

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Uncertainty representation & evaluation in the Safety Assessment

- Deterministic vs. probabilistic approaches
- Conservative & bounding values/assumptions
- Specific scenarios to assess potential consequences of possible site evolutions
- Stylized approaches
- .....

- applying statistical methods on relevant (measured) data
- modelling
- quantification by expert judgement
- accuracy of measurements and detection limit of equipment
- exclusion of poor quality/inappropriate data

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Identification of uncertainties that need to be reduced, mitigated or avoided

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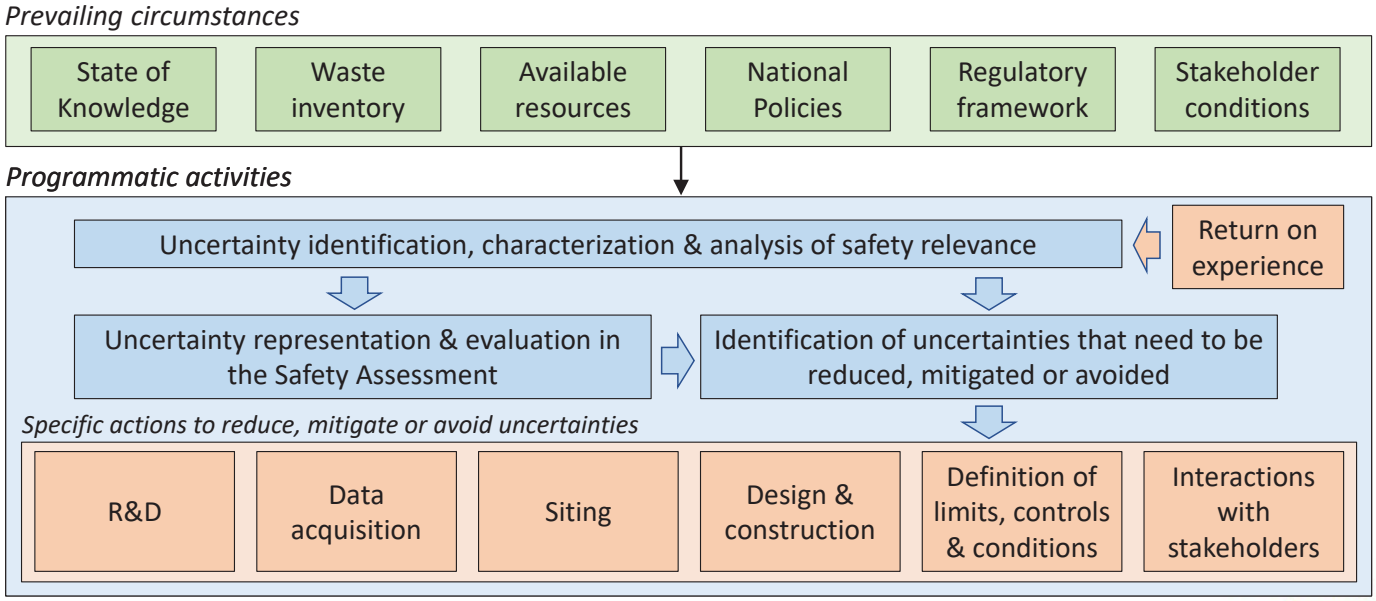
Uncertainty representation & evaluation in the Safety Assessment

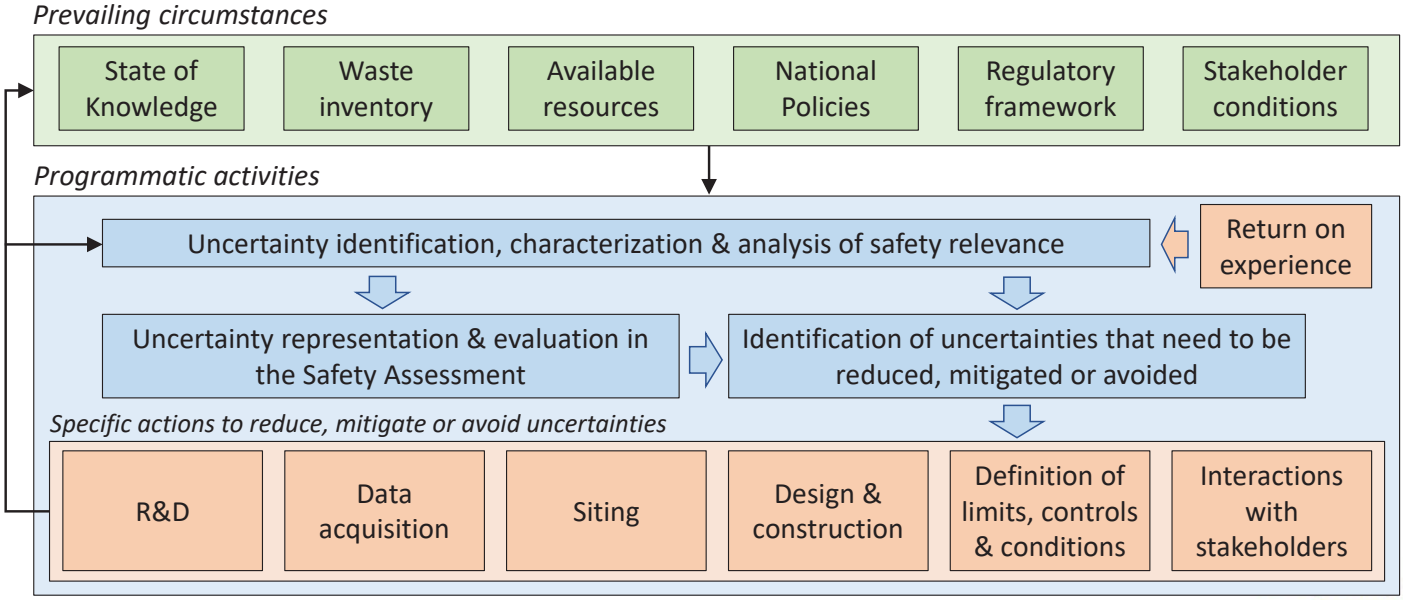
Identification of uncertainties that need to be reduced, mitigated or avoided

Specific actions to reduce, mitigate or avoid uncertainties

ELEMENTS OF AN UNCERTAINTY MANAGEMENT STRATEGY

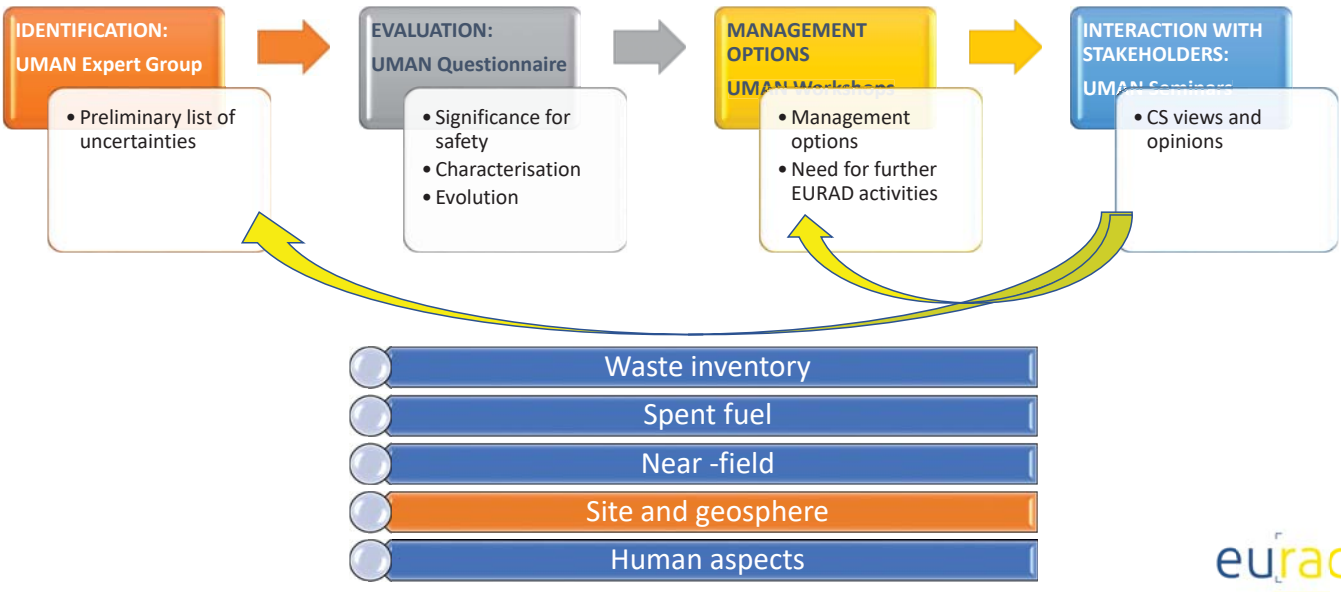


ELEMENTS OF AN UNCERTAINTY MANAGEMENT STRATEGY



Application of the methodology to uncertainties associated with site and geosphere

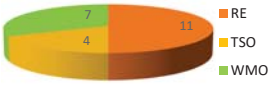
IMPLEMENTATION OF UMAN METHODOLOGY



SITE AND GEOSPHERE

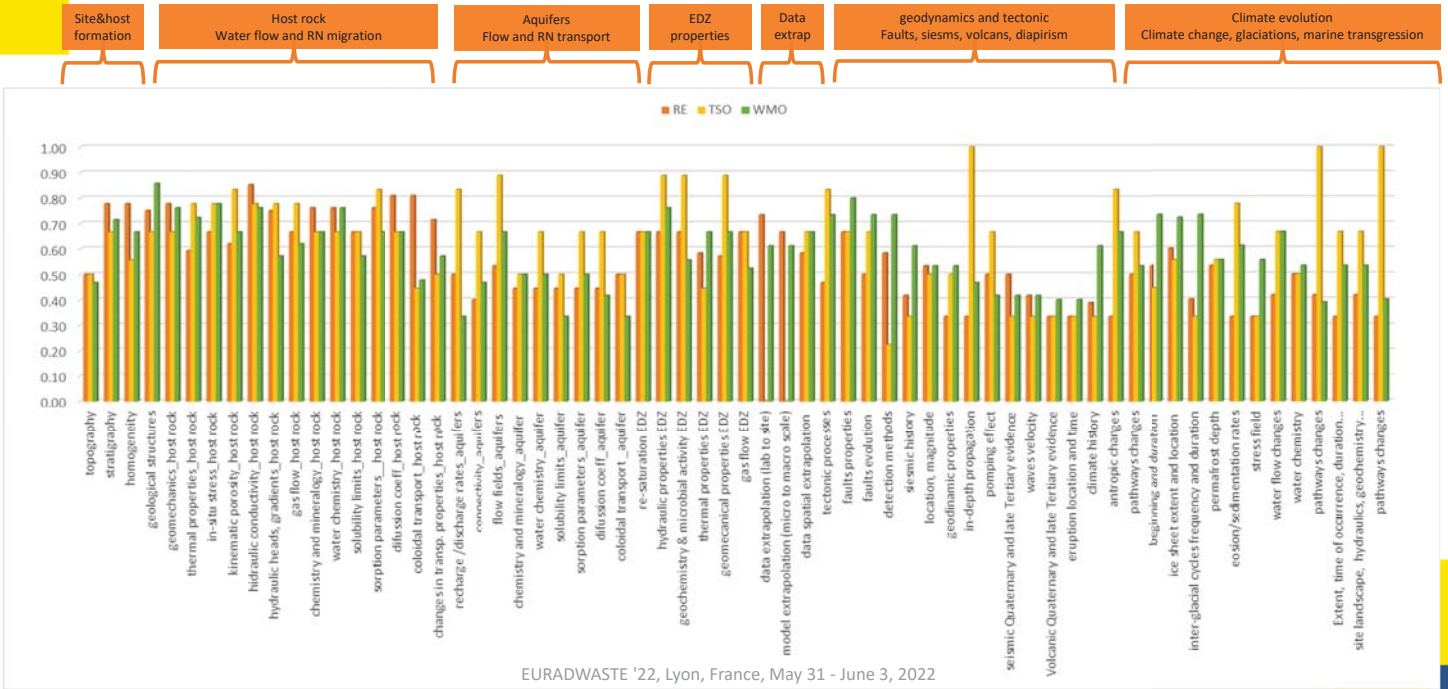
Survey on a comprehensive list of uncertainties

- 15 topics – 64 parameters and processes → 22 answers



Uncertainties to be taken into consideration when conceptualizing natural barriers and aquifers	Uncertainties associated with geodynamics and tectonic perturbations of the site in the long-term	Uncertainties associated with future climate changes
A. Structural and geometric data of the host rock and surrounding geological layers and aquifers B. Thermal and mechanical properties of the undisturbed host rock C. Hydraulic conditions and liquid and gas flow in the undisturbed host rock D. EDZ properties E. Hydraulic conditions and properties of adjacent aquifers F. Geochemistry and solute transport properties in the host rock G. Geochemistry and solute transport properties in the adjacent aquifers H. Data and model representativeness	I. Tectonic processes and structures J. Earthquakes K. Diapirisms L. Volcanic occurrence in the regions	M. Climate changes (other than glaciations) N. Glaciations O. Marine transgression and regressions

UNCERTAINTIES ON SITE & GEOSPHERE: SIGNIFICANCE FOR SAFETY



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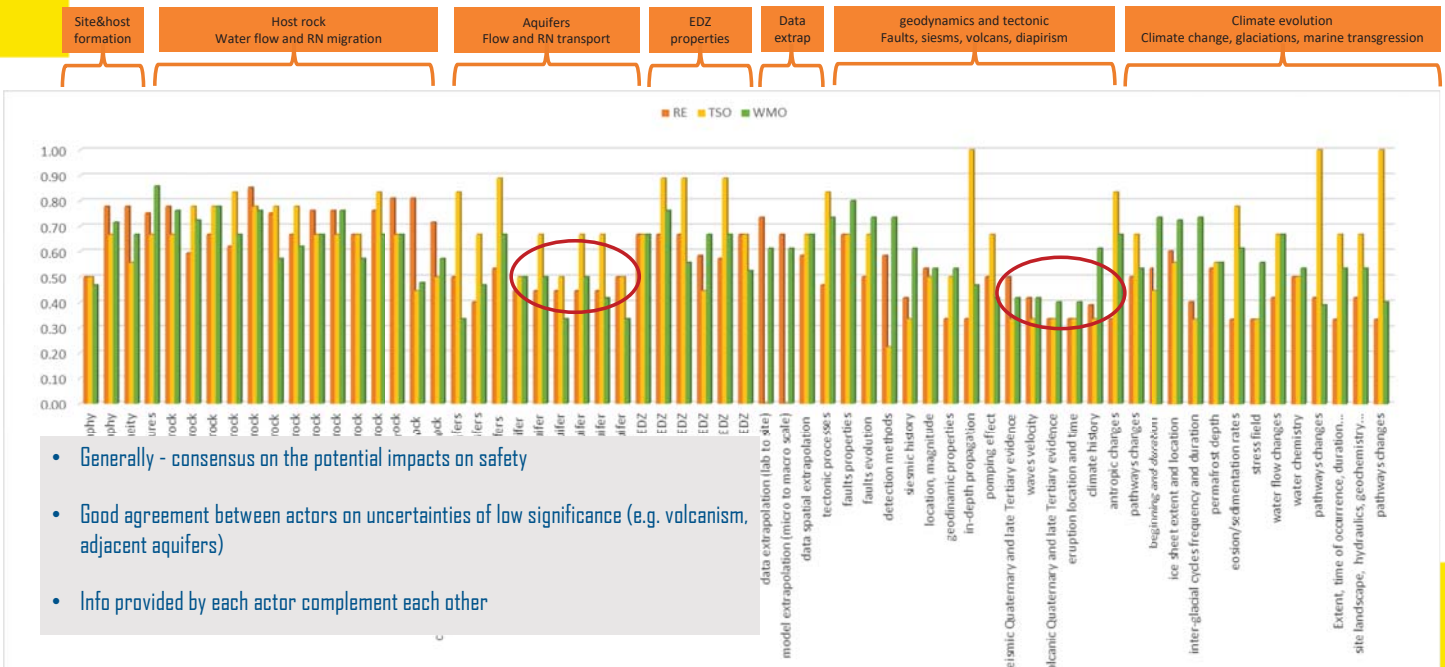
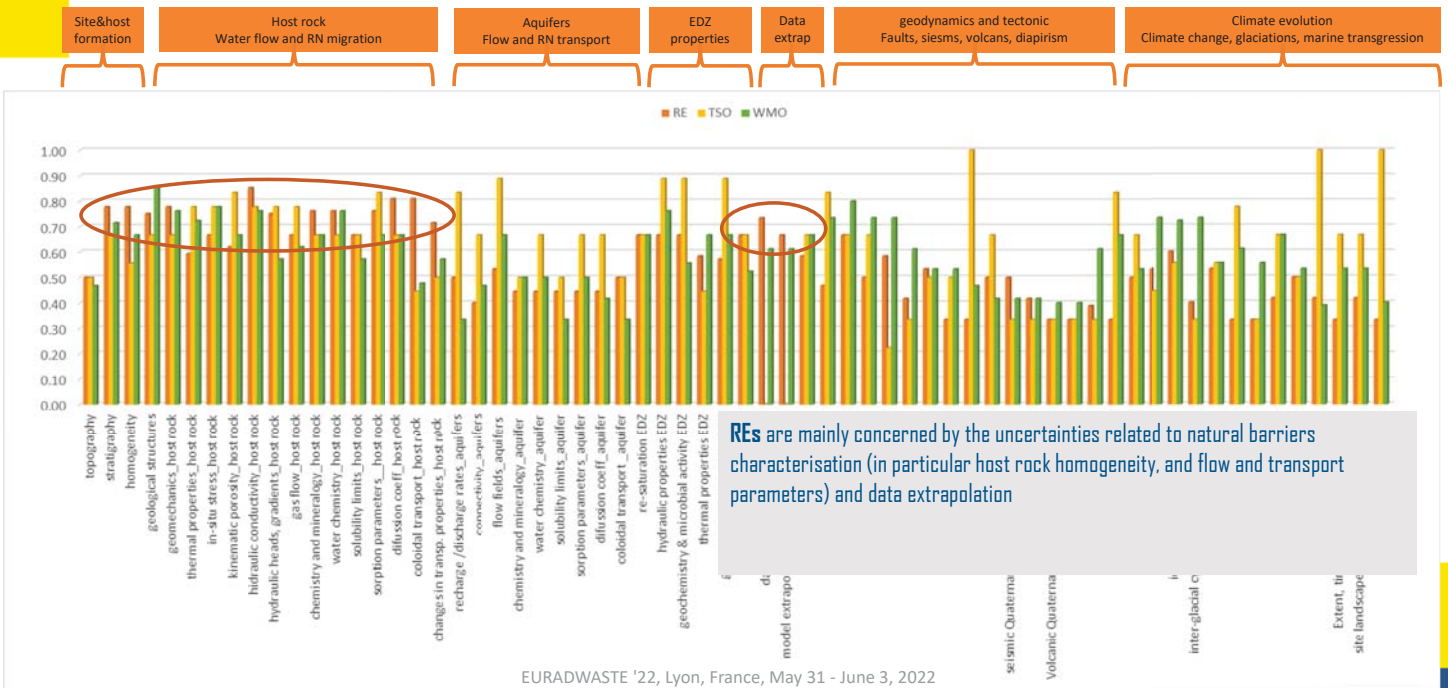


- Generally - consensus on the potential impacts on safety
- Good agreement between actors on uncertainties of low significance (e.g. volcanism, adjacent aquifers)
- Info provided by each actor complement each other

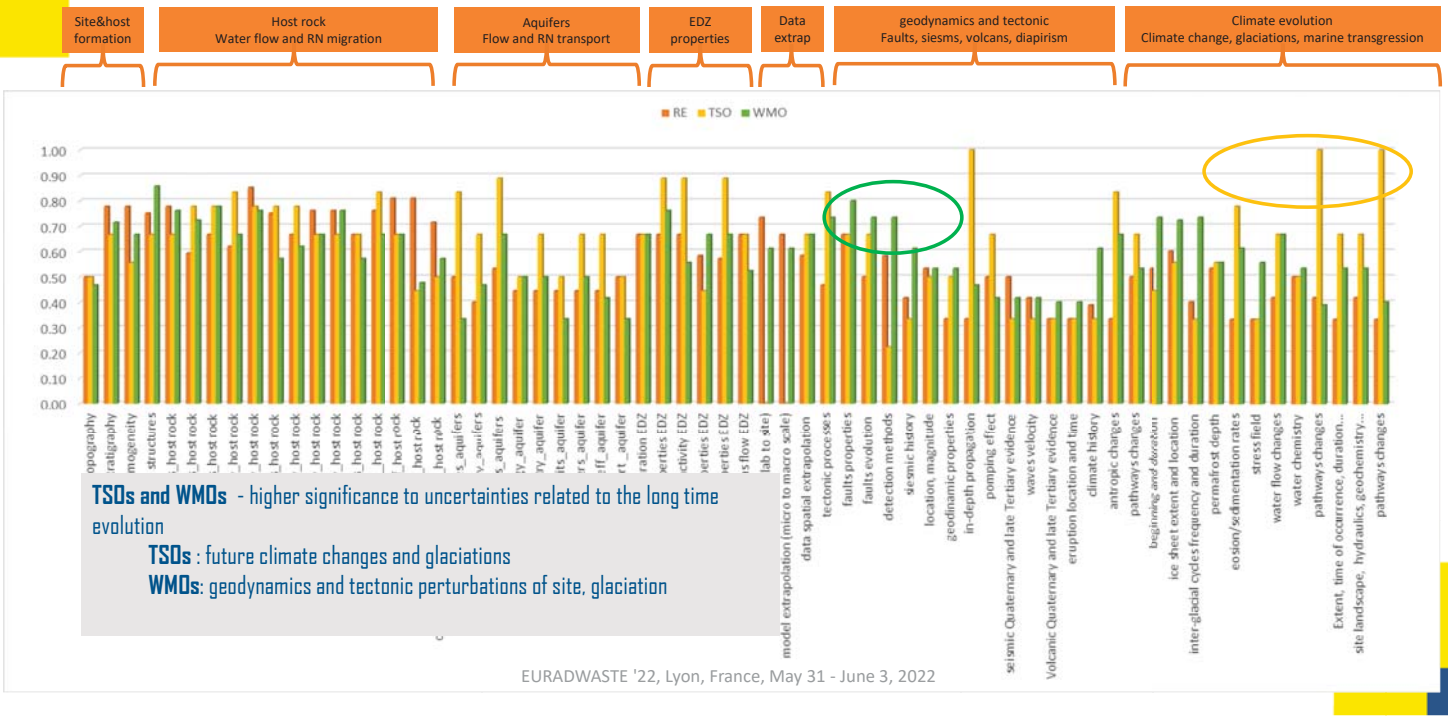
UNCERTAINTIES ON SITE & GEOSPHERE: SIGNIFICANCE FOR SAFETY



REs are mainly concerned by the uncertainties related to natural barriers characterisation (in particular host rock homogeneity, and flow and transport parameters) and data extrapolation

EURADWASTE '22, Lyon, France, May 31 - June 3, 2022

UNCERTAINTIES ON SITE & GEOSPHERE: SIGNIFICANCE FOR SAFETY



TSOs and WMOs - higher significance to uncertainties related to the long time evolution

TSOs : future climate changes and glaciations

WMOs: geodynamics and tectonic perturbations of site, glaciation

SITE AND GEOSPHERE SAFETY RELEVANT UNCERTAINTIES

5. Uncertainties associated with FEP completeness

		Known unknowns	Unknown/Ignored Knowns	Unknown Unknowns
1. Programme uncertainties				
2. Uncertainties associated with initial characteristics	**Hydraulic conductivity**	Upscaling errors, saturation recovering		
	Sorption	Speciation, anionic species, reversibility, Organic Matter		Other processes speeding up migration
	Faults	Locations, detection Undetected faults		
	Heterogeneities of host rock	Discontinuities; anisotropy, gradients		
3. Uncertainties in the evolution of the disposal system & its environment	**Faults**	Reactivation	new faults formation	
	Climatic evolution (glaciations)	Start &duration Isostatic adjustment Ice thickness Erosion Permafrost layer and temperatures	Depth and location of glacial erosion (mapping quaternary sediments)	**Evolution of glaciation**
4. Uncertainties associated with data, tools & methods used in the safety case	**Sorption**	Kd - measurement and models accuracy	Changes in geochemistry	
	Heterogeneities of host rock	Transport properties		

MANAGEMENT OPTIONS - UMAN WORKSHOPS

What UMAN Workshops are?

- Platform for **networking** among WMOs, TSOs and REs
- Identify the **views and preferences** of WMOs, TSOs and Res
- Identify and understand **differences** among these views and preferences (if any)
- Identify **remaining and emerging issues/needs for future EURAD activities** (RD&D, KM or strategic studies)
- **Input for UMAN Seminars (with CS participation)**

Preferred Management strategy

- **Iterative approach**
- **Taking into account different views of actors**
- **Not all uncertainties are accessible to rigorous statistical assessments**
- **Main steps identified in management uncertainties :**
  - Identification
  - Analysis of safety relevance (initial programme phase)
  - Uncertainty characterization
  - Classification and associated actions (reduce / bound / mitigate)
  - Conceptualisation in Safety Assessment/Performance Assessment.

MANAGEMENT OPTIONS

identification and safety relevance
characterization
classification
conceptualization in SA/PA

Hydraulic conductivity	Sorption	Homogeneity	Faults	Glaciations
Site characterization	Creation of knowledge	Site characterization	Creation of knowledge	Creation of knowledge
Safety assessment with sensitivity/uncertainty analysis	Safety assessment with sensitivity/uncertainty analysis	Safety assessment with sensitivity/uncertainty analysis	Screening of FEP's list	Screening of FEP's list
Laboratory and field tests	Laboratory and field tests	Statistical methods on data	Safety assessment	Safety assessment with sensitivity analysis
Statistical methods on data	Statistical methods on data	Modelling	Geological mapping	Modelling
Consideration of accuracy of measurements	Consideration of accuracy of measurements	Site characterization	Modelling	Site characterization
Modelling at laboratory and field scale	Modelling	Engineering solutions	Site characterization	Alternative and 'What if' scenarios
Conservative assumptions (if necessary) for deterministic calculation	Site characterization	Conservative assumptions (if necessary) for deterministic calculation	Engineering solutions	
Stochastic modelling	Conservative assumptions (if necessary) for deterministic calculation	Stochastic modelling	Alternative and 'What if' scenarios	
	Alternative scenarios			
	Stochastic modelling			

MANAGEMENT OPTIONS – MAIN OUTCOMES

Management options related to site&geosphere

- Generally – good agreement on UM strategy
- Preferred uncertainty management options - might differ among EU members, depending on **host rock and the associated safety concept**.
- further discrepancies may result from the **actors' role**
- Iterative approach and communication/regular dialog with stakeholders, particularly with the public, **as a very important part of the general management strategy**.

- **WMOs and TSOs** - interested in developing management strategy for safety-relevant uncertainties in compliance with the requirements.
- **REs –** oriented to much broader investigations towards a sound scientific basis for a mechanistic understanding of the processes and for assessing safety significance, including also processes that are not safety relevant

Management options	CNRS	LEI*	RATEN ICN*	SCK-CEN	STUBA
Site characterization	x	x	x	x	
Safety assessment with sensitivity/uncertainty analysis		x	x		
Statistical methods on data	x		x	x	
Modelling	x	x	x		
Site characterization	x	x	x	x	
Engineering solutions		x			
Conservative assumptions (if necessary) for deterministic calculation		x	x	x	
Stochastic modelling	x	x	x		

EXCHANGES ON UMAN SEMINARS

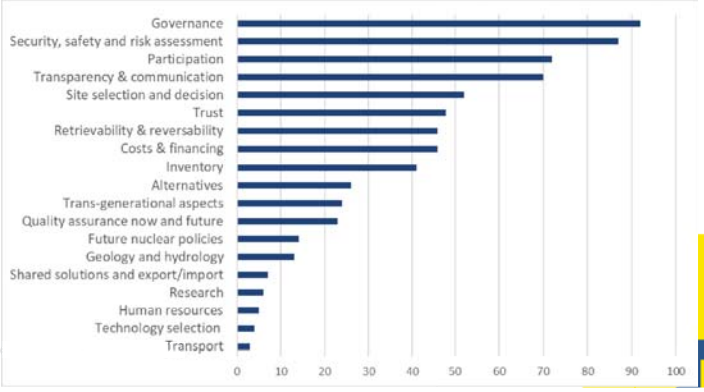
- **Why UMAN Seminar ?** - to perform a pluralistic analysis of UMAN key outcomes and enlarge the results.
- **Who ?** Different types of mandated actors + Civil Society, regulatory bodies and international organisations
- **How?** Integrative process of yearly seminars

Seminar 1 - global perspective on uncertainties and their management

- Technical uncertainties can be addressed, but non-technical/programme uncertainties which matter to CS are also important
  - related to the "process" (governance) & stakeholder involvement
  - related to knowledge management (transfer of data over generations,...)

Seminar 2 focused on "**Site Geosphere uncertainties**"

- Preferences regarding uncertainties management options
- Possible evolutions of uncertainties throughout the different phases of a disposal programme
- **How the interactions with CS could contribute to manage uncertainties ?**



EXCHANGES ON SEMINAR 2

Uncertainties:

- fault detection
- climate evolution (future glaciation)
- sites' natural resources

General approach:

- Safety significance – technical view
- Perspectives of CS group involved in EURAD
- Working Group discussions based on concrete cases
- Restitution of WG and generic discussion

Generic outcomes:

- Stepwise, transparent and flexible decision-making process needed for managing these uncertainties
- Possibility and means for CS to be involved early in this R&D process and to monitor the situation now and in the future (rolling stewardship ?)

Climate evolution:

- transparent protocol, scenarios regularly and pluralistically assessed, model's deviation → trigger for dialog
- two-levels discussions:
  - **level of experts** (including non-institutional experts) to exchange on technical knowledge,
  - **experts and stakeholders** to discuss programme, roadmaps and also decisions.
- discussion on climate models should foresee a longer-term interaction between government, experts and society.

OUTLOOK

- Workshop on Human Aspects (June 2021)
  - **Public acceptance of the repository at potentially suitable or projected locations,**
  - **Schedule to be considered for implementing different phases of disposal programme**
  - **Adequacy of safety-related activities during construction for the implementation of safety provisions**
  - **"New knowledge"**
- Workshop on Spent Nuclear Fuel (February 2022)
  - **Fuel history data, reactor operation and irradiation conditions.**
  - **Nuclear data** (e.g. cross-sections, fission product yields, decay data)
  - **Performance of spent nuclear fuel (SFN) during (dry) interim storage** (e.g. degradation mechanisms)
- Workshop on Waste inventory (with participation of LABONET) – April, May 2022
  - **Uncertainties on the physico-chemical conditions in the storage or disposal facility**
  - **Uncertainties on the radionuclide activity (including the scaling factor)**
  - **Uncertainties on the chemical composition (with a special attention to organic content)**
- Workshop on Near Field (2nd wave) – March-April 2023
  - Survey on going at EURAD level

Seminar on Human Aspects (14-15 June 2022)

Seminar on Spent Nuclear Fuel (October 2022)

Seminar on Waste inventory (October 2023)

Course on Uncertainties Management (November 2022)

SOME RECOMMENDATIONS ON R&D ACTIVITIES

Theoretical studies with respect to uncertainties on:

- **long-term effects:** future climate changes, effects on host rock and biosphere
- **structural geology** in combination with geochemistry and geostatistics

Experimental studies

- **Hydraulic conductivity** - **time for clay saturation** - diffusion/advection in host rock, plugs&seals; hydraulic conductivity of host rock and EDZ; H2 production by containers corrosion or cement enforcements, H2 transport, counter pressure build-up)
- **Sorption of anionic species** - **large scale** diffusion experiments in clay for low but non-zero Kds
- **Lab scale** - identification of relevant sorption processes / mechanism, mechanistic sorption models - bottom up approach for Kd understanding.for improved sorption models
- **upscaling** from batch systems on pure phases to the real host rock in confined conditions

Computer codes development

- **geochemical codes** enabling to make a direct use of uncertainties based on pdfs or other representations, combining uncertainty components in a model other than additive, which led to unrealistic results due to uncertainty propagation
- **Glagiations -** coupled climate-permafrost-flow models; Validation of permafrost depth models; Influence of decompaction on host rock properties from analogues and modelling

SOME RECOMMENDATIONS ON GUIDANCE/SOK/STRATEGIC STUDY

Strategic studies

- **Climate changes** - common approach how to treat climate changes (glaciation periods) - not restricted to national borders.
- **Homogeneity** - identification of what is really understood by "homogeneity" - within what degree of variation of what safety relevant property (retention, hydraulic or thermal conductivity, fracture mechanics,....) a host rock volume is considered homogeneous.

CONCLUSIONS

- There is a large number of actors invilved and various types of uncertainties (technical, scientific, social, politic, financial,…). that must be managed in a disposal programme
- Management of uncertainties should include all activities aimed at identifying, recording, characterizing, classifying, analyzing, treating, assessing, reducing, avoiding and mitigating any type of uncertainties and involves different categories of actors.
- Uncertainties management is an iterative approach evolving all along the programme implementation.
- Uncertainties significance for safety and management options depend on the repository type, stage in the programme implementation and actor' role.
- There are available several options to reduce, avoid or mitigate uncertainties, which have been identified and validated by WP UMAN.

THANK YOU FOR YOUR ATTENTION !