CLIMATE TASK 3 : RESULTS OF THE SCREENING OF CLIMATE IMPACTS ON CONSTRUCTION AND OPERATION

Near-surface disposal and climate change - Topical Session 4 (CLIMATE and SUDOKU)

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INTERACTIONS BETWEEN WP 18 SUDOKU AND WP 11 CLIMATE

Near-surface disposal optimization based on knowledge and understanding

To deepen the current understanding of the behaviour and performance of multilayer covers and cementitious barriers in near-surface disposal facilities.

SUDOKU Task 3: Performance of multilayer covers	CLIMATE Task 3 : Construction and operational phase climate impact
SUDOKU Task 4: Evolution of reinforced and unreinforced cementitious barriers	CLIMATE Task 4 : Post-closure climate impact
SUDOKU Task 5: Modelling	

Interaction approach CLIMATE-SUDOKU : Performance of multilayer cover & Modeling

1. **What is expected impacts on the multilayer cover system by the screened climate hazards?**
2. **How can climate hazards propagate the exposure and vulnerability on multi-layered cover?**
3. **Example of climate impact modeling on a Near surface disposal facility**

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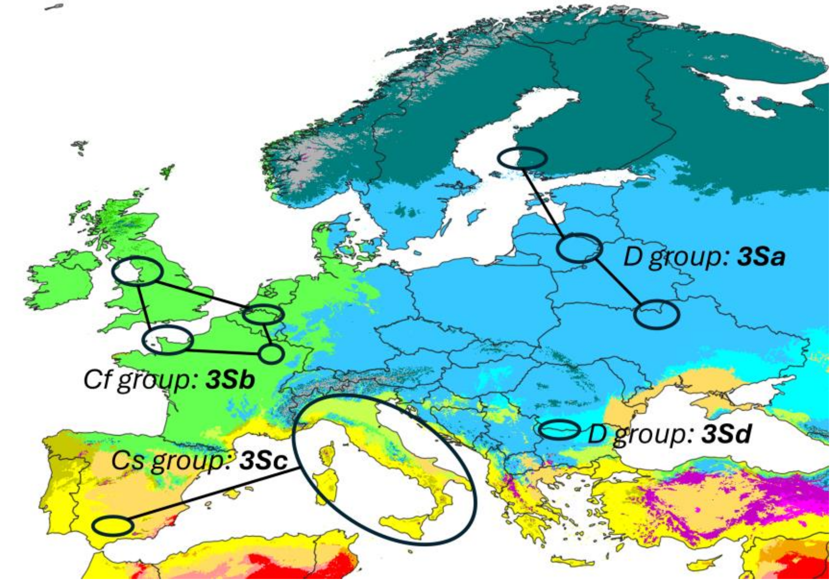
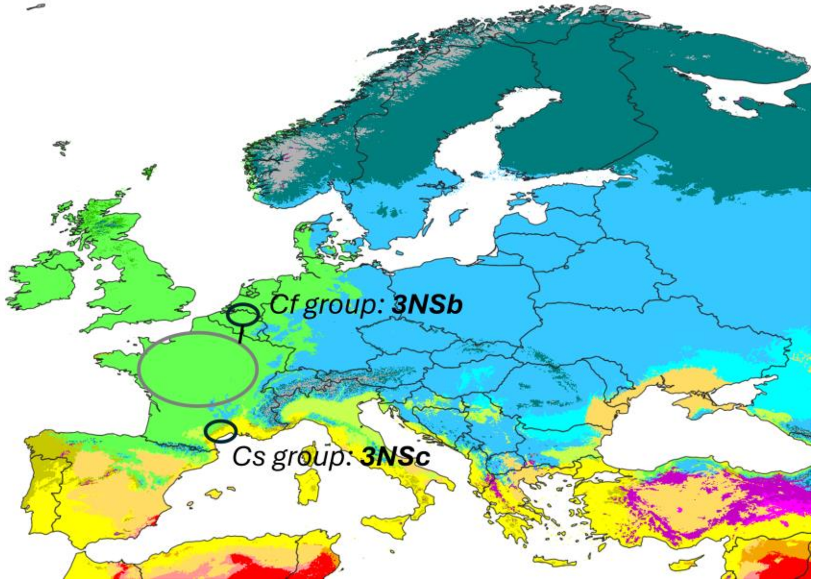
CLIMATE GROUPS IN CLIMATE-TASK 3



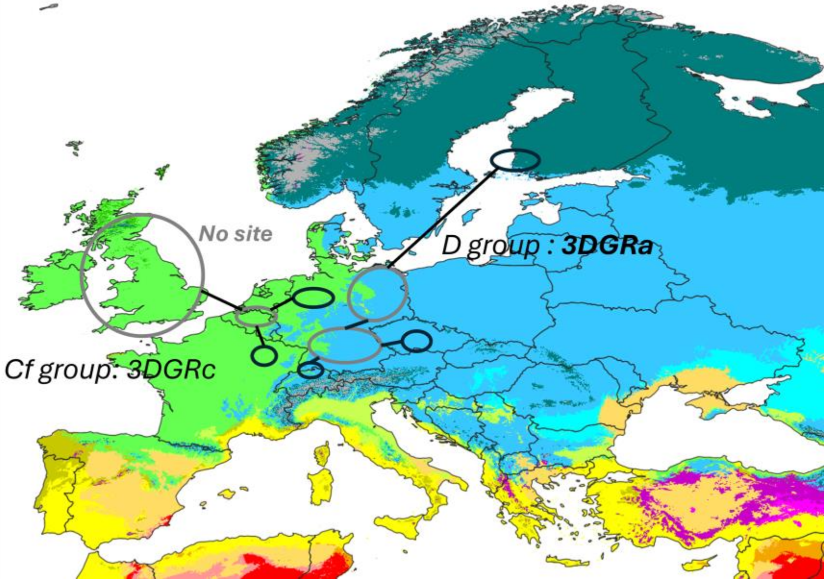
Surface disposal facilities

3Sa	Surface	D	Finland, Ukraine, (Lituania)
3Sb	Surface	Cf	Belgium, UK, France
3Sc	Surface	Cs	Spain, Italy
3Sd	Surface	D	Bulgaria



Near-surface disposal facilities

3NSb	Near-surface	Cfb	Belgium, France
3NSc	Near-surface	Cs	France



DGR facilities

3DGRa	Deep Geological	D	Finland, Germany, Czechia, Switzerland
3DGRb	Deep Geological	C	Germany, UK, Belgium, France

1. WHAT IS EXPECTED IMPACTS ON THE MULTILAYER COVER SYSTEM BY THE SCREENED CLIMATE HAZARDS?

SUDOKU-CLIMATE	3Sa	3Sb	3Sc	3DGRa	3DGRb	Int. Storage
Heavy Rainfall	●	●	●	●	●	●
Flash flooding	●	●		●	●	
River flooding	●	●	●	●	●	●
Coastal flooding	●	●		●	●	●
Cold Spells	●	●		●	●	
Droughts	●	●	●	●	●	●
Desertification			●			
Soil Erosion	●	●	●			

CLIMATE ONLY	3Sa	3Sb	3Sc	3DGRa	3DGRb	Int. Storage
Heat waves	○	○	○	○	○	○
Landslides	○			○	○	
Permafrost thaw						
Sea Level Rise	○	○				○
Water Table variations	○	○	○		○	
Windstorm	○	○	○	○	○	
Wildfires			○			

2. HOW CAN CLIMATE HAZARDS PROPAGATE THE EXPOSURE AND VULNERABILITY ON MULTI-LAYERED COVER?

Climate Hazard	Hazard Indicators	Exposure Indicators	Vulnerability Indicator	Expected Impacts
Heavy Rainfall	• Maximum daily precipitation intensity, duration, frequency • Extreme precipitation	• Surface drainage system capacity • Cover system slope and length	• Cover system erosion • Performance of runoff and drainage system	• Increased infiltration through cover system • Enhanced erosion/degradation of protective cover • Slope instability
Flash Flooding	• Daily/Peak precipitation intensity	• Facility elevation relative to drainage network	• Emergency response capability • Backup drainage system capacity	• Inundation of surface structure and control • Accelerated erosion of cover and slope failure
River Flooding	• Daily/Peak precipitation intensity, duration, discharge rates	• Critical facility distance and elevation to rivers	• Site-specific Flood protection design • Drainage system capacity	• Slope instability and erosion of cover system
Coastal Flooding	• Storm surge and wave height, return period • + Sea level Rise	• Horizontal distance to coastline	• Concrete durability under marine exposure	• Saltwater intrusion into shallow aquifer affecting barrier chemistry

2. HOW CAN CLIMATE HAZARDS PROPAGATE THE EXPOSURE AND VULNERABILITY ON MULTI-LAYERED COVER?

Climate Hazard	Hazard Indicators	Exposure Indicators	Vulnerability Indicator	Expected Impacts
Cold Spells (Cold waves)	• Minimum temperature, duration, intentisy	• Heat-sensitive equipment	• Material minumum operating temperature	• Concrete and Steel degradation
Droughts	• Drought severity, duration, frequency	• Fire risk areas and protection system	• Drought contingency plan	• Barrier desiccation and soil erosion • Increased fire risk
Desertification	• Average temperature and dry duration	• Average and maximum historical temperature • Longest dry period	• Water demand	• Soil cover erosion • Larger wildfire frequency
Soil Erosion	• Frequency of high-intensity precipitation events • Thickness of multilayer coverage • Total and Maximum-consecutive dry days	• Surface cover slope angles and area density	• Cover layer materil composition, thickness and compaction	• Loss of multi-layer cover system integrity • Slope instability and erosion

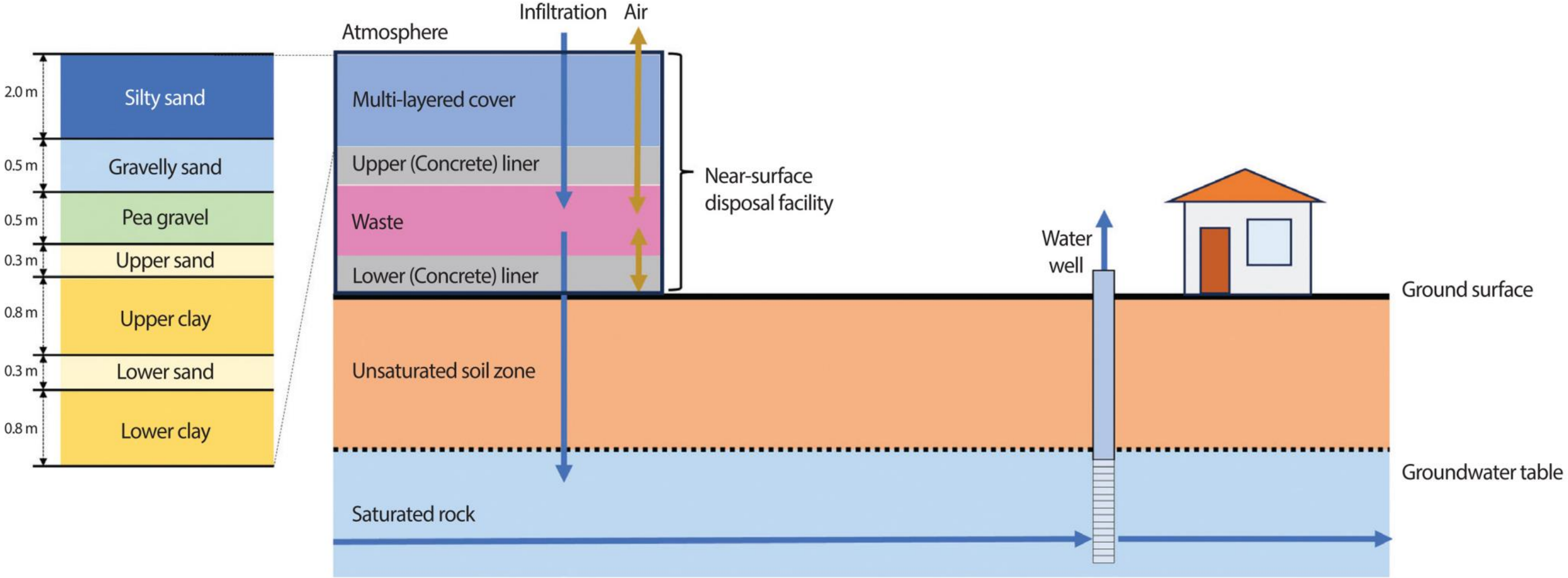
2. HOW CAN CLIMATE HAZARDS PROPAGATE THE EXPOSURE AND VULNERABILITY ON MULTI-LAYERED COVER?

- **Interdependencies, cascading and combined climate hazards**
  - Heavy rainfall → Flash Flooding → Soil erosion
    → River Flooding → Slope Instability → Infrastructure Damage
  - Coastal Storm → Storm Surge → Coastal Flooding → Groundwater Intrusion
    \+ Sea level rise (compound saltwater intrusion)
  - Heatwave → Drought → Soil Desiccation → Barrier Degradation

- Drought + Heatwave + Windstorm + (Desertification + Wildfires) causing dust mobilization, heat stresses personnel and equipment, and **impact on integrity of the (multi-layer) cover structure**
- Drought + Extreme precipitation changes affecting **soil cover erosion of the (multi-layer) cover structure**

3. EXAMPLE OF CLIMATE IMPACT MODELING ON A NEAR SURFACE DISPOSAL FACILITY

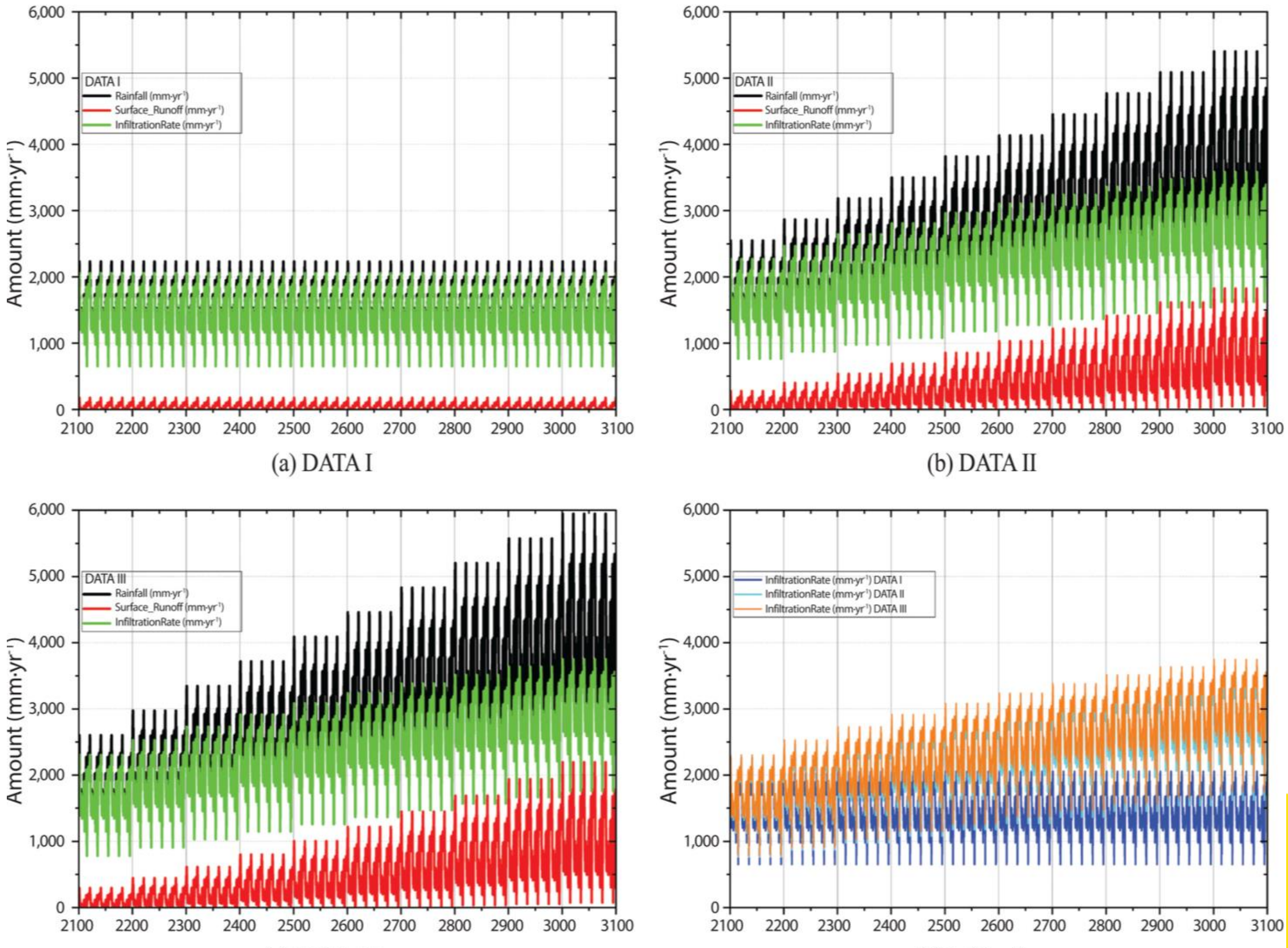
- **In Example,**
  1. Setting up rainfall and infiltration scenarios on a multi-layered cover system by the historical data
  2. Infiltration flow modeling from atmosphere through top silty sand to the saturated rock area
  3. Radionuclide transport modeling for radionuclide concentration at the disposal domain



Impact of Rainfall Patterns on a Near-Surface Radioactive Waste Disposal Facility: Climate Change and Long-Term Perspectives, Journal of Nuclear Fuel Cycle and Waste Technology, DOI: dx.doi.org/10.7733/jnfcwt.2025.016

3. EXAMPLE OF CLIMATE IMPACT MODELING ON A NEAR SURFACE DISPOSAL FACILITY

- **Conclusion**
  1. Discussion on ^{3}H, ^{14}C, ^{99}Tc, ^{90}Sr, ^{129}I, and Total annual dose ($mSv \cdot yr^{-1}$)
  2. Surface runoff rate is crucial for understanding water balance among rainfall, surface runoff and final infiltration.
  3. Thickness of the saturated rock zone can contribute to the annual dose and needs to be discussed.
  4. It is essential to consider alternative and probabilistic scenarios to estimate the impact of extreme precipitation on the cover system.
  5. In addition to establishing an alternative scenario, it is recommended that potential maximum rainfall reflects future evolutions due to climate change.



(a) DATA I (b) DATA II (c) DATA III (d) Infiltration

SUMMARY

1. **What is expected impacts on the multilayer cover system by the screened climate hazards?**
   - Type of expected hazards : Heavy rainfall, Flash/River/Coastal Flooding, Cold spell(Coldwaves), Drought, Desertification and Soil erosion
   - For a near-surface disposal facility, it can be expected that the enhanced erosion/degradation of protective cover, Slope instability, Saltwater intrusion, Concrete/Steel degradation, Larger wildfire frequency, and Loss of multi-layer cover system integrity.
2. **How climate hazrds can propagate the exposure and vulnerability on multi-layered cover?**
   - Interdependencies, cascading and combined climate hazards need to be considered in modeling.
   - Identified climate hazard can applied to prepare an alternative scenario in safety assessment.
3. **Example of climate impact modeling on a Near surface disposal facility**
   - It is essential to consider alternative and probabilistic scenarios to estimate the impact of extreme precipitation on the cover system.
   - In addition to establishing an alternative scenario, it is recommended that potential maximum rainfall reflects future evolutions due to climate change.

THANK YOU FOR ATTENTION