SESSION

Spotlight on cutting-edge science

European Partnership on Radioactive Waste Management

GUIDANCE ON THE LONG-TERM PERFORMANCE ASSESSMENT OF MKPC AND PC-BASED WASTEFORMS

PhD: Study of Al corrosion and its implications for H_2 generation in LILW repositories

CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

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LILRW IMMOBILISATION: THE LONG-TERM CHALLENGE

Metallic waste streams

1. Surface decontamination
2. **Metal immobilisation**

Metals	**Passivation pH range**
Be	5.3 – 13.5
Steel	≥ 9.8
Mg	11 – 14
Al	4 – 9
U	Up to 12

OPC-CEM I matrix
pH: 12.5-14

$$2Al + 6H_2O \rightarrow Al_2O_3 \cdot 3H_2O + \mathbf{3H_2}$$

Risk: metal corrosion, pressure build-up & explosions

What long-term performance means?

Maintaining the coupled evolution of the metal, the matrix and the environment under control, so that the wasteform continues to fulfil its safety function throughout its service life:

- *Limited metal degradation over time.*
- *Controlled H_2 gas generation.*
- *Durable and chemically stable matrix under evolving conditions.*

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WASTEFORMS FOR LONG-TERM ASSESSMENT

More compatible matrices than widely used OPC

Blended Portland cement-based

(OPC + FA, SF)
low-pH (< 11)

Non-Portland cement-based

MKPC (neutral-pH)

(MgO + KH_2PO_4 + retarder + filler)

300-year safe waste immobilisation

Short-term scenery

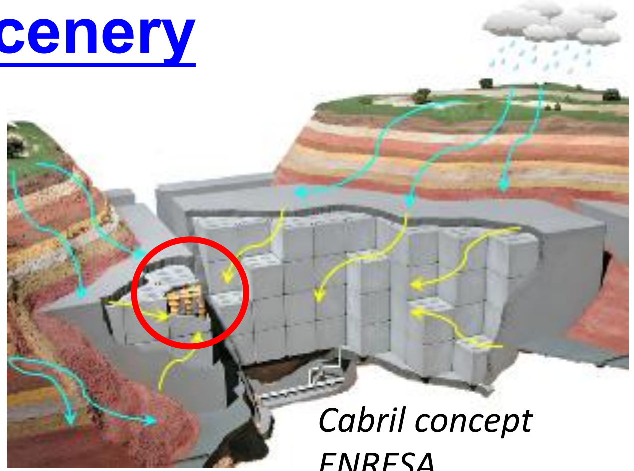
Operational phase
+
post-closure

Metal-matrix interaction

Long-term scenery

Post-closure

Environmental interaction



Cabril concept ENRESA

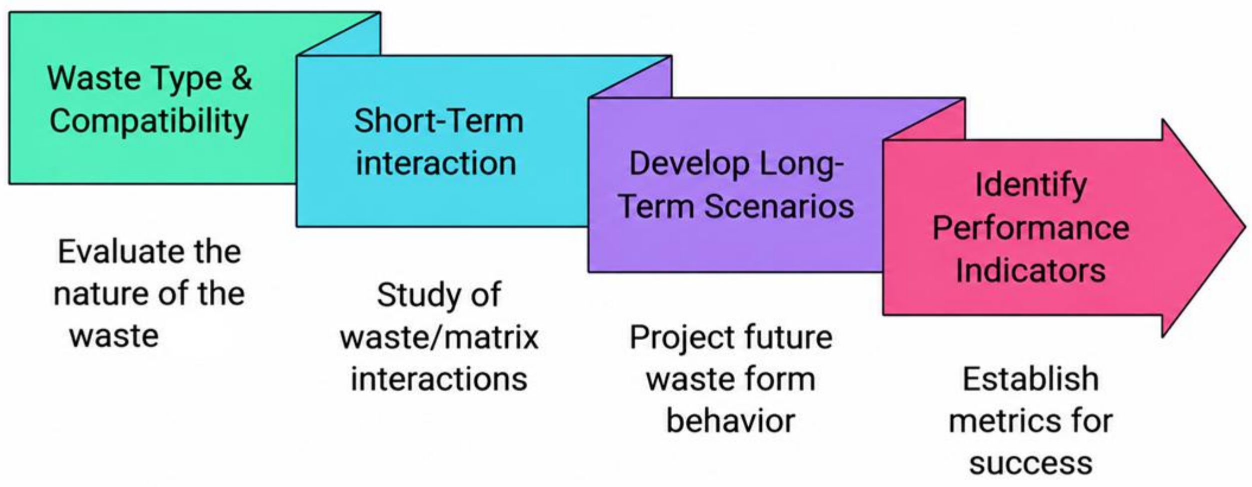
WHY LONG-TERM PERFORMANCE MATTERS

To demonstrate that cementitious wasteforms can safely encapsulate aluminium and its alloys by controlling corrosion and H_2 generation.

Can the wasteform maintain its **function under relevant storage and disposal conditions**?

DEFINITION OF ASSESSMENT METRICS

From PhD research to long-term performance assessment…



KEY PERFORMANCE INDICATORS (KPI):

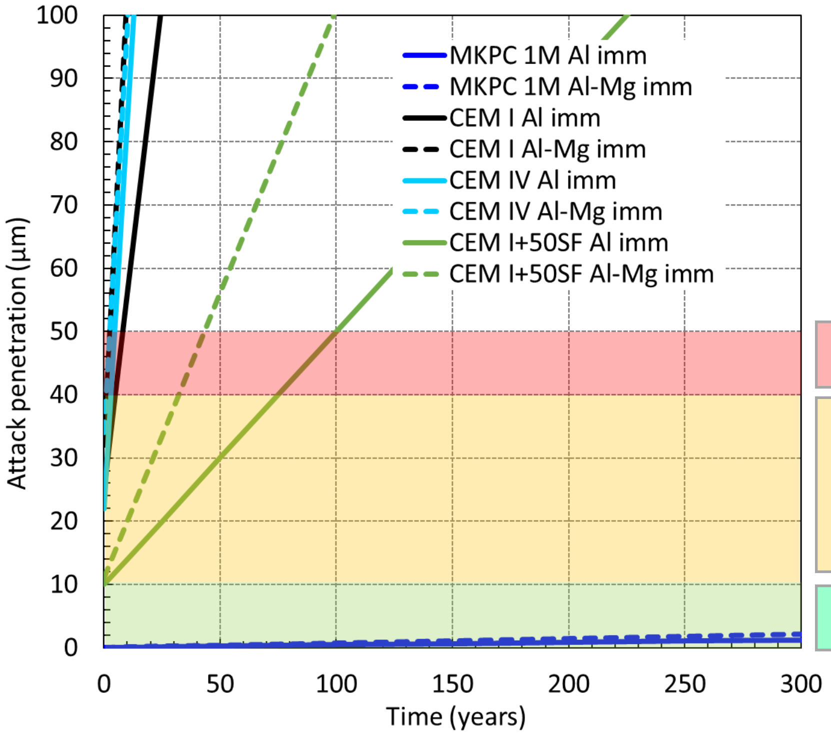
1) **Attack penetration**: how far degradation progresses into the metal.
2) **H_2 generation risk**: whether gas accumulation may become problematic.
3) **Matrix stability**: whether the binder remains physiochemically robust.

These metrics translate a complex scientific problem into operational guidance

PERFORMANCE INDICATORS ON METAL

KPI 1: ATTACK PENETRATION

Depth of degradation relative to the contaminated metal surface by radioactivity



Zhong et al. 2021

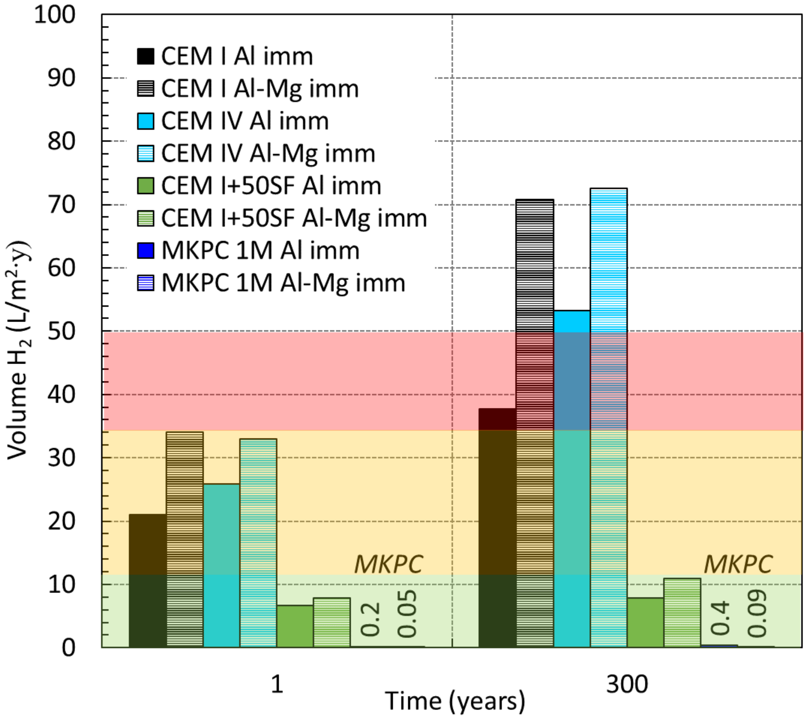
40-50 µm (<0.1%)

10-40 µm (<2%)

0-10 µm (>98%)

KPI 2: H_2 GENERATION RISK

Gas accumulation inside the 220-L drum (pressure build-up, fire, explosion hazards)



(HNF-9411, 2001) USA Department of Energy

>15%; >33L

5-15% 11-33 L

<5%; <11L

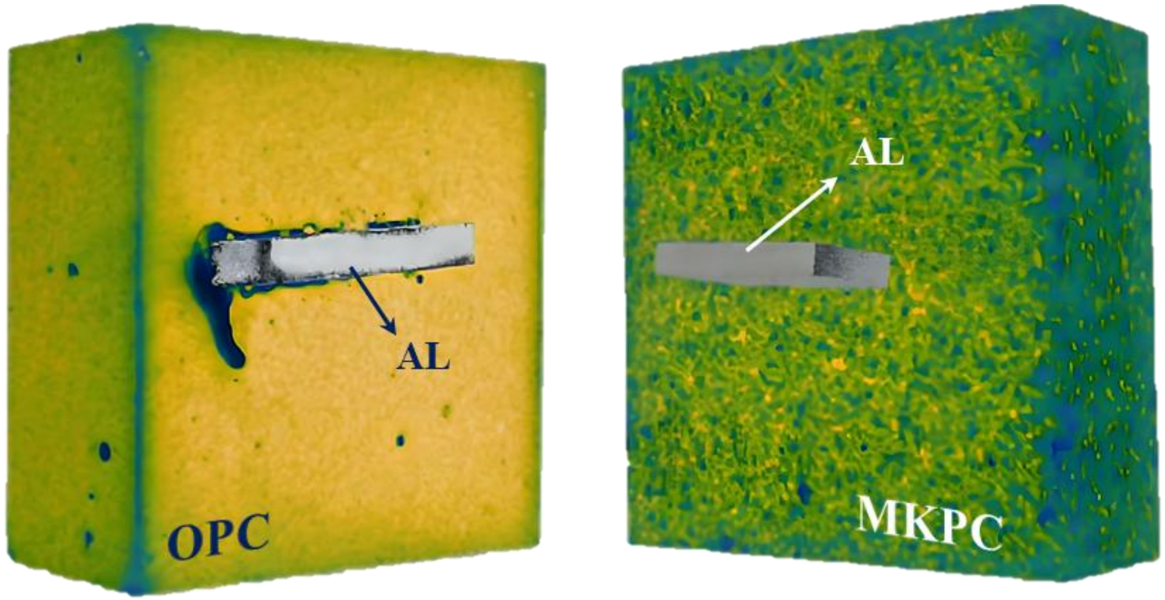
From corrosion kinetics of aluminium degradation

PERFORMANCE INDICATOR IN MATRIX

KPI 3: STABILITY

Binder type

- PC-based
  - Dense matrix, low-porous, alkaline (↑H_2), porous interfaces
- MKPC
  - Porous matrix, Neutral pH (↓H_2), compact interfaces
  - MgO Type, retarder, curing…



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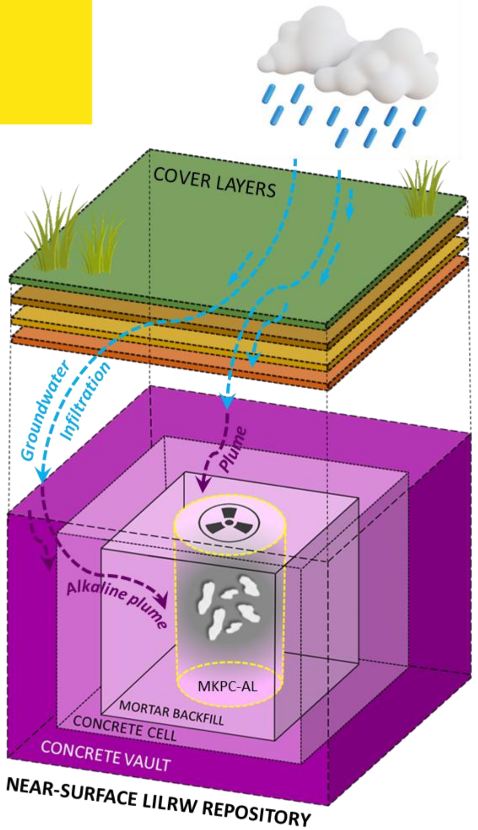
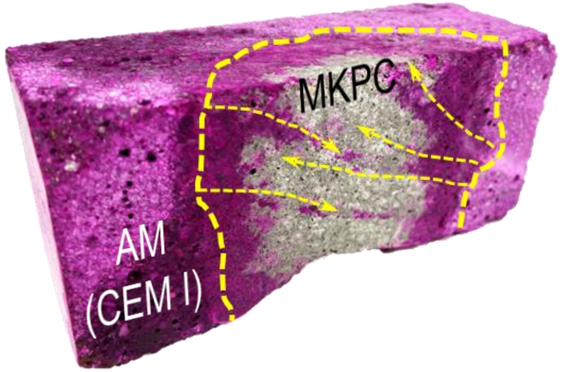
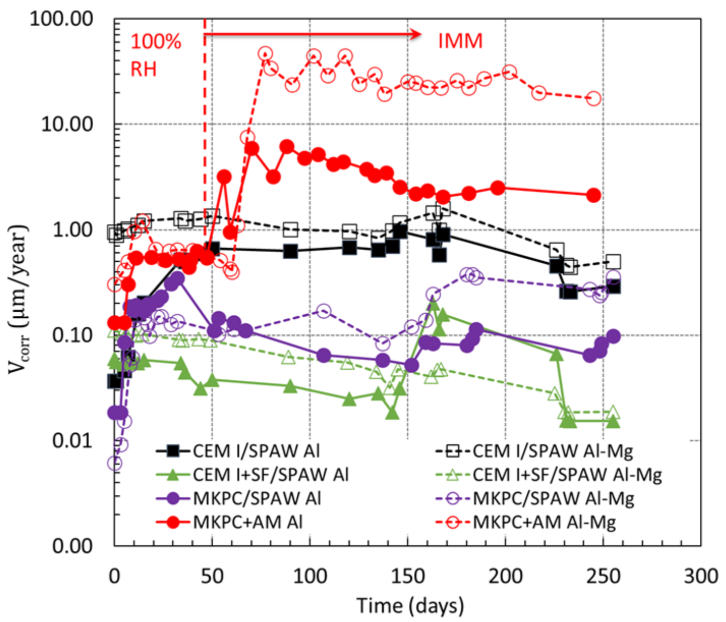
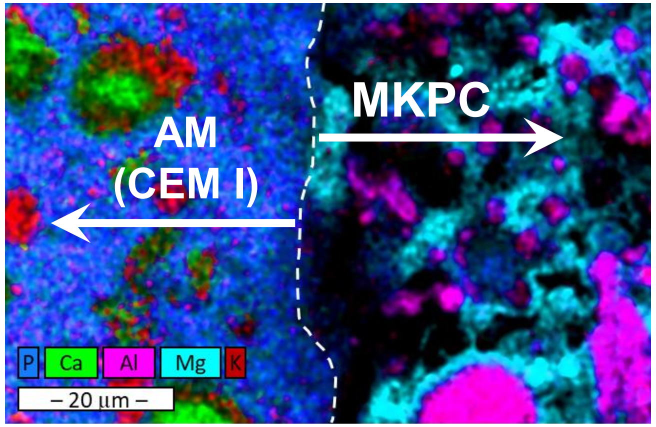
PERFORMANCE IN A REAL LONG-TERM SCENARIO









MKPC matrix alteration

MKPC

MKPC exceeds the defined limits under a realistic long-term scenario

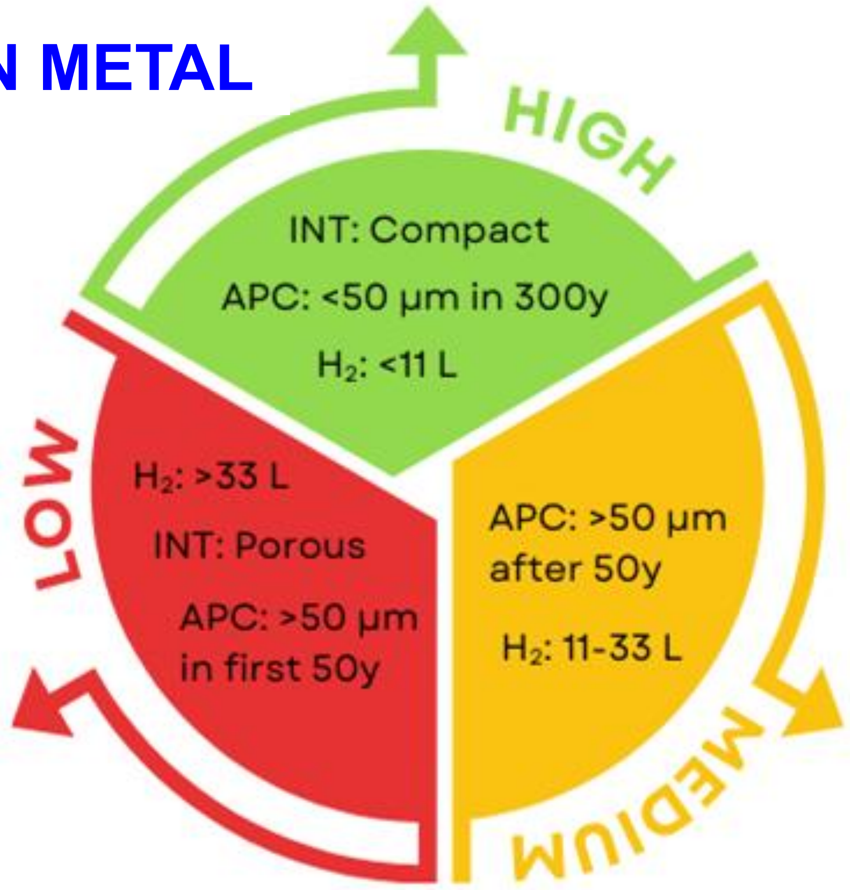
Low-pH PCSF

Improved long-term performance driven by the pozzolanic hydration of SF under alkaline conditions

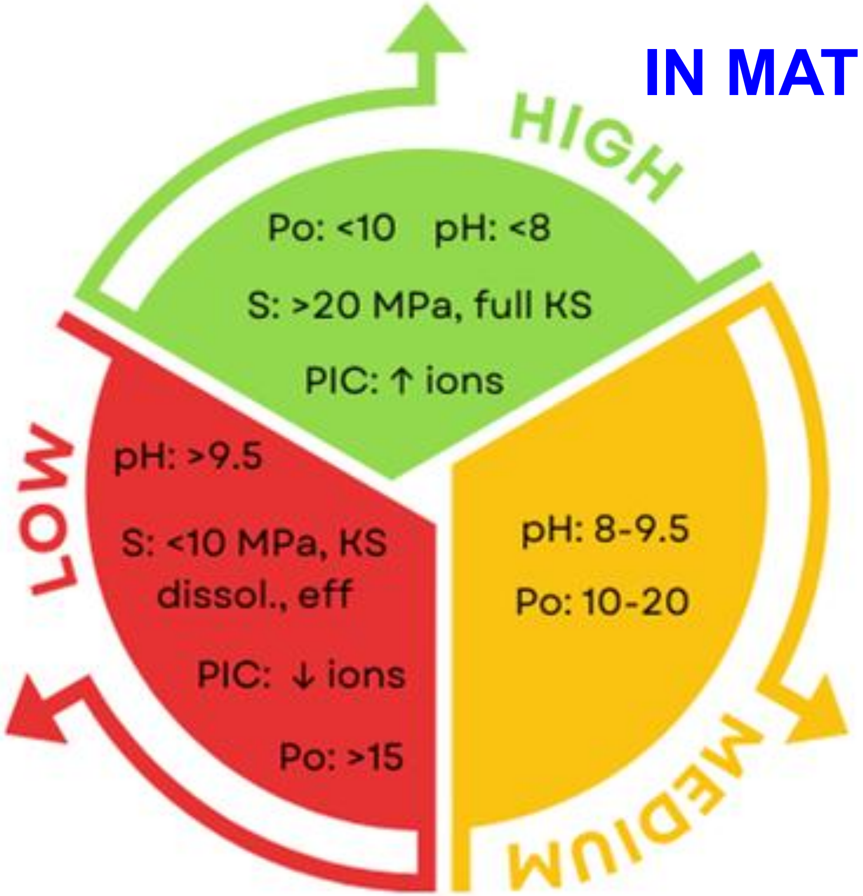
DEFINITION OF WASTE ACCEPTANCE CRITERIA

Performance-based WACs – Dual approach

ON METAL



IN MATRIX



OPC: High incompatibility with Al

Long-term safety: MKPC 1M + Low-pH PCSF

SCIENTIFIC OUTPUT

Overall PhD thesis

"Study of aluminium corrosion in different cement-based wasteforms designed to inhibit hydrogen evolution"

1. **Corrosion Behaviour** and Immobilisation of Pure Aluminium and Al-Mg Alloys in Magnesium Potassium Phosphate Cement. J. Nucl. Mater. 2023, 582, 154501.

2. **MgO/KH_2PO_4 and Curing Moisture** Content in MKPC Matrices to Optimise the Immobilisation of Pure Al and Al-Mg Alloys. Materials. 2024, 17(6), 1263.

3. Interaction of Aluminium Alloys with MKPC and Portland-Based Cements at the **Metal–Matrix Interface**. *Appl. Geochem*. 2024, 172, 106105.

4. Passivation of Aluminium A1050 in MKPC Matrices: Effect of **MgO Type and Chemical Retarder Composition**. *Electrochim. Acta*. 2025, 525, 146104.

5. Aluminium Corrosion Reactivation in MKPC and Portland-Based Wasteforms Under Simulated **Alkaline Repository Conditions**. *J. Nucl. Mater*. 2025, 616, 156064.

6. Mechanistic Role of **Phosphate and Borate Species** in Aluminium Passivation in Simulated MKPC Pore Solutions. *Electrochim. Acta*. 2026, 546, 147824.

7. **Magnesium Potassium Phosphate Cement** for Low- and Intermediate-Level Radioactive Waste Conditioning: Advances, Limitations and Future Trends. *J. Nucl. Mater*. (Under review).

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European Partnership on Radioactive Waste Management

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