



Objectives and first achievements of PREDIS WP5

Maxime FOURNIER (CEA), maxime.fournier@cea.fr

Federica PANCOTTI (SOGIN), pancotti@sogin.it

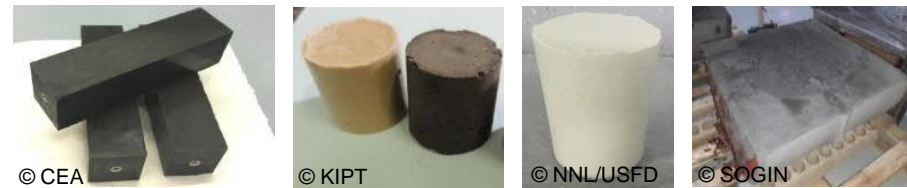
Catherine DAVY (Ecole Centrale de Lille), catherine.davy@centralelille.fr

David LAMBERTIN (CEA), david.lambertin@cea.fr



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 945098.

PREDIS WP5 Objectives

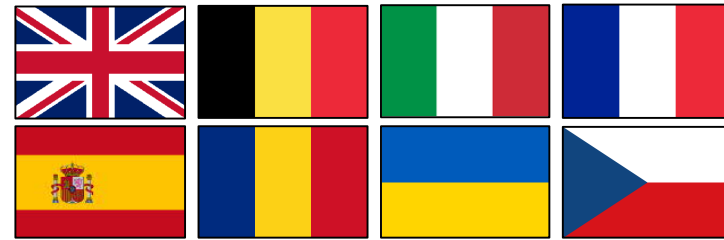


- Study of **innovative geopolymers** and their **interactions with RLOW**.
- Development of **direct conditioning solutions** for RLOW from **TRL3 to TRL6** including **validation tests** (real waste) and feasibility **scale-up** tests.
- **Optimization** of geopolymers and formulations for RLOW encapsulation, especially **waste loading** and **matrix performance**.
- Process **robustness** regarding waste, raw materials and process variability including study of the **stability** and **durability** of the final waste form.
- **Disposability assessment** related to Waste Acceptance Criteria and scientific approaches for deeper physico-chemical understanding.

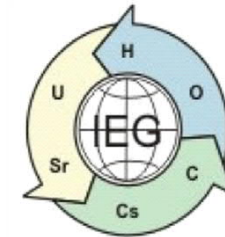
PREDIS WP5 Relevance

- **Societal issue.** Contribution to a **sustainable management of radioactive waste**, limiting the burden to future generations.
- **Environmental and nuclear safety issues.** Long-time storage of large volumes of RLOW awaiting treatment raises questions about nuclear safety and their potential environmental impact (flammability, toxicity, radiolysis...)
- **Technical issues.** Development of **flexible and versatile innovative solutions** that can cover a large part of RLOW without management route.
- **Industrial and economic issues.** Solutions must be acceptable from **technical and economic** points of view for all actors including Waste Management Organisations and RLOW owners.

PREDIS WP5 Partners



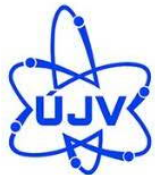
sck cen



IMT Atlantique
Bretagne-Pays de la Loire
École Mines-Télécom



Ciemat



IRSN
INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

MINISTERUL ENERGIEI
RA TEN
REGIA AUTONOMĂ
TEHNOLOGII pentru ENERGIA NUCLEARĂ



UNIVERSITÀ DI PISA



The
University
Of
Sheffield.



POLITECNICO
MILANO 1863

Total effort: 617 Person/Months, among 19 partners



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 945098.

PREDIS Webinar
30/03/2021

PREDIS WP5 Structure

Task 2: Collection & review of waste, regulatory, scientific & technical data



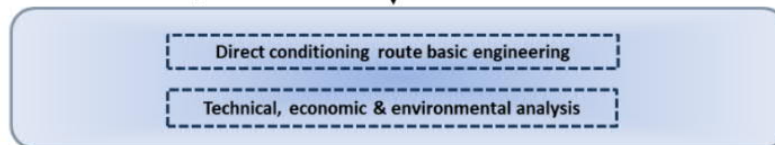
Task 3: R&D – Study of direct conditioning process



Task 4: R&D – Study of conditioning matrix performances



Task 5: technical, economic, environmental analysis



Task 1: WPs Management

Task 6: Implementation & Dissemination

- Task 1 WP5 Management
- Task 2 Collection and review of waste, regulatory, scientific and technical data
- Task 3 Study of direct conditioning process
- Task 4 Study of conditioning matrix performances
- Task 5 Preliminary technical, economic and environmental analysis
- Task 6 Implementation and dissemination

PREDIS Task 5.3 Study of direct conditioning process

	Sep-20	Oct-20	Nov-20	Dec-20	Jan-21	Feb-21	Mar-21	Apr-21	May-21	Jun-21	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21	Jan-22	Feb-22	Mar-22	Apr-22	May-22	Jun-22	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22	Jan-23	Feb-23	Mar-23	Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23	Nov-23		
	YEAR 1												YEAR 2												YEAR 3																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39		
TASK 5.3: STUDY OF DIRECT CONDITIONING PROCESS									MS32		MS33																MS34														D5.2
Subtask 5.3.1 Definition of experimental protocols																																									
Subtask 5.3.2 Formulation of conditioning materials: feasibility study & screening conditions options (5 to 10)									MS32		MS33																														
Subtask 5.3.3 Formulation of conditioning materials: optimization & robustness of reference formulation																											MS34														
Subtask 5.3.4 Investigation of reference formulations with real ROLWe																																									
Subtask 5.3.5 Investigation of direct conditioning process scale-up																																									
Subtask 5.3.6 Synthesis of experimental results																																									D5.2

- **Assess** exploratory conditioning options (5-10) and to select most promising reference formulations (3) to be further studied and developed (**MS32**)
- **Optimize** and assess robustness of selected reference formulations (**MS34**)
- **Further consolidate** reference formulations from tests with real RLOW
- **Investigate** feasibility of scale-up from exploratory pilot scale tests

PREDIS Task 5.3 – First achievements and outcomes

Sub-task 5.3.1 - Definition of the experimental guidelines and protocols that will be used during the laboratory activities and of some general acceptance criteria range for the experimental tests



Working Document
Task 5.3.1 - Experimental guide
22/12/2020 version 1 Final
Dissemination Level: Public

Test	Acceptance Criteria (Range Values)	Note
PHASE 1		
Viscosity after mixing or workability (fluidity)	> 80 %	
Rotational Viscosity after mixing	(1-200 mm at 1500 rpm time)	
Heat reaction	Exothermic < 1000 mJ/g for low viscosity mix. Must be below 7 Pa.s for current in-Drum mix processes	
Flowing	NA	
Setting Time	< 2%	
PHASE 2		
Compressive Strength	$3 \times 10^6 < F_c < 40$	
Flexural Strength	$F_c > 4 \text{ MPa at 7 d, } F_c < 5 \text{ MPa at 28 d, } F_c > 7 \text{ MPa at 90 d}$	The F_c evolution during curing time must be checked (7-28-90) and no large decrease accepted
Water Immersion Test	No spalling or cracks after 28 days of immersion. F_c not less than the value measured after 28 days curing	
Thermal Stability	NA	
Activity of polymer to release liquid under compression	no visually detectable liquid under 50psi	
PHASE 3		
RLOW distribution in the cement matrix	NA	

Sub-task 5.3.2 – Feasibility study & screening conditions options

WPS: KIPT contribution Presented by Eugenio Sotgiu
 *Experiments were done:
 *Set of optimal formulation
 *New materials: metakaolin, fly ash, slag, siliceous ash, zeolite
 *Laboratory equipment: furnace (Haberstrom 1200C), planetary mill (grinding and mixing power component), vibrating table for casting the mold
 *Mechanical measurements and strength test
 *Results
 *Adding pump oil and obtaining samples
 *Measure of all components and procedure the paste
 *Control the paste into plastic mold
 *Viable control and strength test

Conditioning Option
 Direct Solidification Process
 Geopolymer formulations to be tested:
 • 2 x metakaolin powders of varying chemical and physical properties:
 • Flash & Holey Calcined MK with K Silicate/KOH activator within the molar ratio range:
 • 1.0 - 1.4 Si/K ratio
 • 11 - 15 H₂O/SiO₂ ratio
 • 1.0 - 1.5 K/Al ratio
 LIGN Surrogate:
 TBP
 Neovastane: EP100 oil

1. RLOW direct encapsulation in novel tu.
 • Idea: replacement of metakaolin with zeolitized volcanic ash
 • Why?
 • Wide worldwide availability, low cost
 • Zeolites could wrap the radioactive waste (e.g. setting time)
 • Higher Ca content could improve some properties (Roman concrete (opus caementitiu) based on pozzolanic volcanic ash, proved high durability)

Conditioning matrix
 Ground Granulated Blast Furnace Slag
 Alkaline Na-based (Sodium Idr)
 Darsell Ruredil (silica fume)
 Starting from 50%, varying 2 x

Immobilization matrices
 • Geopolymers
 • Metakaolin based geopolymers
 • BFG based alkali activated materials
 • Activated by NaOH + sodium silicate

Conditioning materials
 Mineral ash
 20% Ultrafines
 80% pure SiO₂
 Chemical composition:
 62% SiO₂ - 17% Al₂O₃ - 6% CaO - 4% Fe₂O₃

Activation Additives Waste loading

SOGIN – RAIEN – CIEMAI – KIPT – NNL/USFD NUC – POLIMI – SCK-CEN



This project has received funding from the European Union research and innovation programme under grant agreement

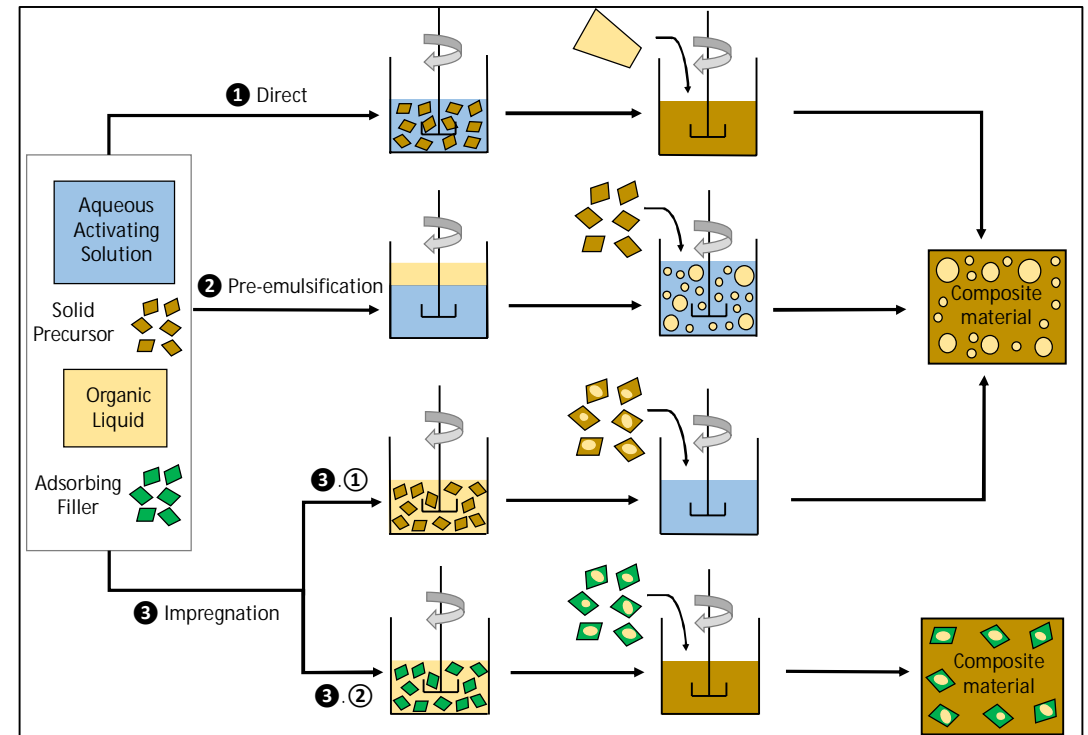
PREDIS Webinar
30/03/2021

PREDIS WP5 – Task 4 : Study of conditioning matrix performances

Making the most of the current crisis:
Gap analysis

Three main processing routes for the **incorporation of OL into alkali-activated materials** have been identified and described in an open access review paper (see reference below).

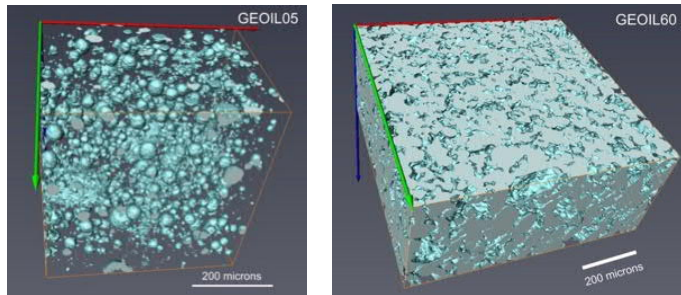
Nota: Incorporation of OL in Portland cement is only achieved for a few %oil



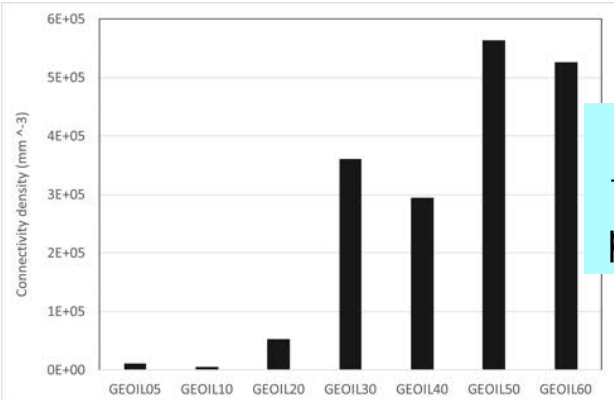
Published as [Reeb et al. Ceramics International, Gold Open Access, DOI: 10.1016/j.ceramint.2020.11.239, 2021]

PREDIS WP5 – Task 4 : Study of conditioning matrix performances

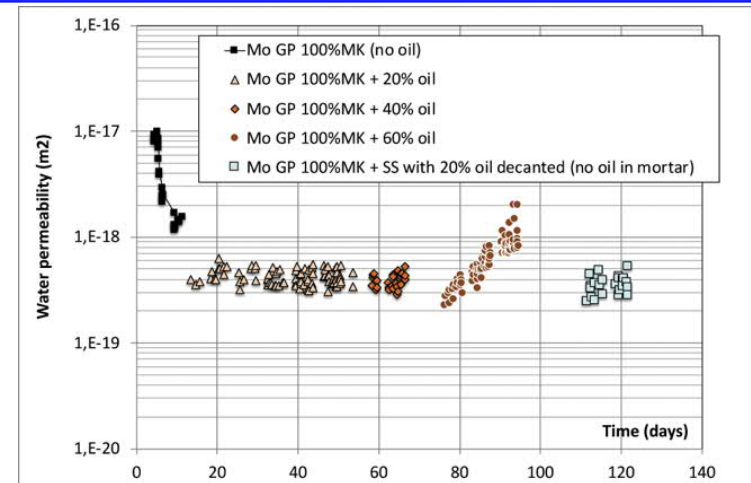
Former research on the [structure and durability of OL/geopolymer composites](#) (direct route)



X Ray micro-CT of oil emulsions (5 or 60%vol) in hardened geopolymer



Without surfactants, the hardened OL/geopolymer percolates from 20-30%vol OL

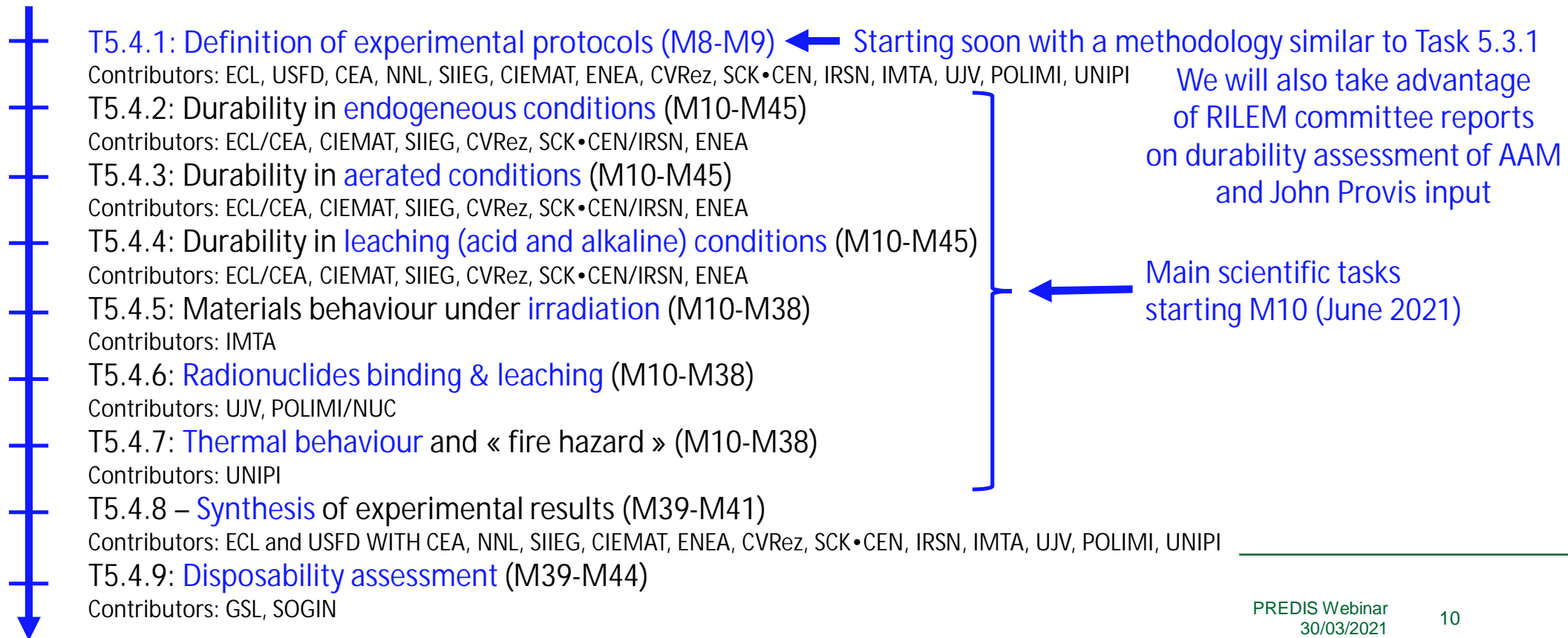


Water permeability of hardened OL/geopolymer mortar is smaller than for mortar alone, and stable with time up to 20%vol oil (no test at 30%)

Published as [Planel et al. Cement and Concrete Research, DOI: 10.1016/j.cemconres.2020.106108, 2020] and [Davy et al. Journal of the American Ceramic Society, DOI: 10.1111/jace.16142, 2018]

PREDIS WP5 – Task 4 : Study of conditioning matrix performances

Structure of Task 4 (i.e. 5.4)





Thank you for your attention !



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 945098.