Geopolymer Webinar Summary

Webinar Date	October 26, 2021
Webinar Time	09:00 to 12:00 CEST
Chair	Erika Holt
Prepared by	Tim Schatz

Background

The PREDIS project hosted an informational webinar (*Geopolymers in Radioactive Waste Management*) on October 26, 2021. Geopolymers are an area of specific interest to the PREDIS community, and this webinar was aimed at reviewing the state of the art, looking at the many connections the PREDIS project itself has to geopolymers, considering different applications and discussing standards and specifications for geopolymers across sectors. The content (see Appendix 1 for agenda) of this webinar is summarised below:

- David Lambertin (CEA) reviewed the characteristics and properties of geopolymer materials and their applications including to the nuclear industry. Geopolymers are alkali-activated materials which form amorphous three-dimensional network structures based on silicon-oxygen and aluminium-oxygen tetrahedrons connected through bridge oxygens. Geopolymer materials are being considered as substitutes for Ordinary Portland Cement (OPC) because of lower carbon dioxide emissions and performance advantages. Geopolymers can be produced from a wide range of natural and waste (industrial, agricultural, municipal) materials and show fire resistance, chemical corrosion resistance, high mechanical strength, and excellent durability. In terms of nuclear sector applications, geopolymers show great promise for the immobilization of liquid organic wastes and cesium containing wastes. Questions remain regarding disposability and regulatory acceptance of geopolymer-conditioned wastes.
- The connections between geopolymers and the work of the PREDIS technical work package and Task 2.3 were briefly summarised. Lumír Nachmilner discussed how WP2 Task 3 on waste acceptance systems views the qualification process for new waste forms (such as geopolymer/conditioned waste) and how this task will provide related guidance. Abdel Abdelouas summarised WP4 involvement in geopolymer-related activities which includes studies of radiation-induced effects on geopolymers, chemical durability assessment and structural and mechanical characterisation. Maxime Fournier explained that WP5 is essentially focussed on geopolymers. Specific objectives include validating and scaling up geopolymer-based, direct conditioning solutions for RLOWs, optimizing waste loading and performance of matrices and providing disposability assessments. Thierry Mennecart indicated that WP6 is involved in the development of geopolymers as alternative binder materials to ordinary cement-based systems for the conditioning of residues and secondary wastes from treatment of RSOWs. Comparisons of geopolymer matrices, to include cost and environmental assessment, for identical wastes will be performed.
- Martin Cyr (LMDC) provided a thorough presentation on aspects of geopolymer durability. Relevant geopolymer features include their amorphousness (results in being less stable than some crystalline phases), weakly bound alkali metals and pronounced, highly connected porous networks. The porous networks show a distribution of pore sizes with large macropores connected to one another by smaller mesopores and have effects on the drying, leaching and carbonation behaviour of the materials. It has also been observed that geopolymer/oil emulsions can have very low water permeabilities. The durability behaviour of geopolymers relative to tests developed for Portland

cement was also discussed. It was emphasized that geopolymers are very different from Portland cements, so they should not (always) be analysed in the same way.

- Tobias Hertel (KU Leuven) described using bauxite residues to produce iron-rich binders. Bauxite residue is a waste product of the alumina industry. The objective of the presented work was to produce alternative binders and monolithic construction materials with high bauxite residue content without compromising properties or performance. It was demonstrated that bauxite residues can be transformed into semi-glassy precursor slag that reacts towards an inorganic polymer binder upon alkali activation. Industrial application and scale-up seems promising as only minor additions of carbon and silica are required, and existing alumina refinery production infrastructure may be applicable. There is also potential for integrated iron recovery with the process. A method for producing calciumsulfoaluminate-ferrite cements with bauxite residue at 36 wt% was also developed. This cement was demonstrated to be fast reacting showing high early strength and having application as an adhesive binder.
- Vaclava Havlova (UJV) discussed the use of geopolymers in the disposal of LILW in the Czech Republic. Geopolymers are used to condition semi-liquid spent resins and sludges from NPP operations. These wastes are packaged in drums and disposed in a vault-type repository which is cement filled. Two commercial products (SiAl© and Alusil©) have resulted from the development of waste conditioning geopolymers in the Czech Republic and Slovakia. These products are based on conventional geopolymer recipes and can be tailored to incorporate specific wastes. Conditioned wastes are demonstrated to satisfy all relevant WAC. Waste loading using these geopolymers is over three times that compared with ordinary cement. As of 2020, close to 6000 drums of geopolymer-conditioned wastes have been produced in the Czech Republic.
- John Provis (University of Sheffield) explained how regulatory issues are approached for geopolymers in non-nuclear sectors. There are three basic options to introduce new materials for acceptance: 1) work within existing specifications, 2) work beyond the scope of existing regulations and 3) develop new, purpose-designed specifications. Standards can be prescriptive or performance based. Prescriptive standards specify ingredients and recipes and, if a material is made as specified, it is assumed to be accepted for use. Performance-based standards define material properties allowing for material innovation and design to meet requirements (as demonstrated through extensive testing). The setting of standards for alkali-activated cementitious materials is an ongoing worldwide concern. The audience was reminded that standards are unlikely to drive applications but can support or enable them and that researchers need to understand standards and develop and apply them appropriately.

The presentations are available on the PREDIS website (https://predis-h2020.eu/geopolymers-in-radioactive-waste-management/).

Following the formal presentation sessions, a set of small group discussions were held. Attendees were randomly assigned to 1 of 3 moderated breakout rooms. The aim of the 30-minute discussion session was to gather perspectives framed around the following questions (although discussions were not limited):

- What are the barriers to wider implementation of geopolymers in RWM?
- Where can PREDIS potentially further contribute to developments in geopolymers?
- Can PREDIS serve as a test bed for verification/demonstration of additional geopolymer processes which are close to deployment?

Geopolymer Webinar Summary

In all, more than 130 participants registered to attend the webinar. Representation was divided between PREDIS end user group members + general stakeholders and consortium partners at 62% to 38%. A total of 99 people joined the webinar over its duration.

Outcomes

Some key takeaways from the deliberations of the discussion sessions were as follows:

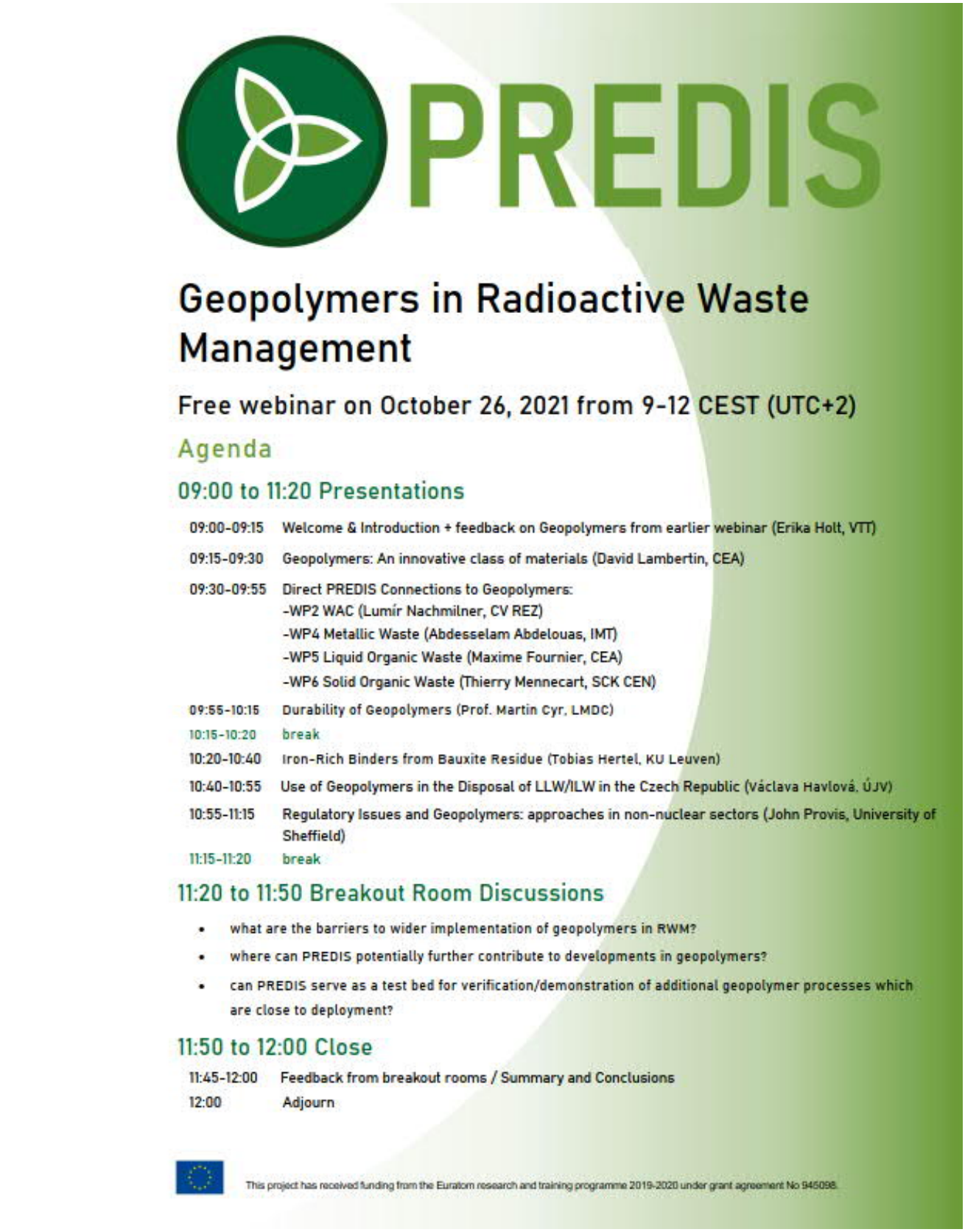
- It seems an odd contradiction that although geopolymers have been used in numerous applications over several decades they are not more extensively utilised in the conditioning of RWs.
- As geopolymers have not been extensively examined for purposes of RW conditioning, they are considered “novel” in this regard and the development of related WAC has not occurred.
- If older conditioning methods are effective there is little to no incentive to develop and implement newer methods unless clear and significant benefits can be established.
- More universal acceptance of geopolymers for conditioning RW will be a long, stepwise process, which starts with producing the simplest configurations (geopolymers + surrogates) and progressing towards more and more complex systems (inactive tracers, active tracers, radioactivity, etc...) until reaching ‘equivalents’ of real waste. The PREDIS project is undertaking work in the earlier stages.
- There will never be one geopolymer formulation which is amenable to all waste types. Rather, there will be several geopolymers as there are several cement types with well-defined compositions and it is likely that geopolymers will evolve towards the same classification principle. PREDIS can serve as a hub to exchange information and experimental feedback in order to guide geopolymer users toward the best formulations according to the type of waste and conditioning requirements.
- Questions regarding durability of geopolymers must be addressed. Modelling approaches and aging protocols need to be developed.
- PREDIS could specifically contribute to greater implementation of geopolymers through:
  - providing advice on which waste streams can be effectively managed,
  - providing transparent information on technology development,
  - continued promotion of the use of the technology,
  - offering training opportunities,
  - performing feasibility studies,
  - developing a “decision-tree” to showcase when geopolymers are an effective option,
  - carrying out drum-scale level demonstrations to increase confidence,
  - documenting case studies indicating where and why geopolymers worked well.

Live-polling indicated (see Appendix 2 for all live-polling results) that:

The majority of respondents registered for the geopolymer webinar to increase their general knowledge.

Respondents thought geopolymer conditioning would be suitable/beneficial for a wide range of waste streams.

Appendix 1. PREDIS Radioactive Waste Characterisation Webinar Agenda



PREDIS

Geopolymers in Radioactive Waste Management

Free webinar on October 26, 2021 from 9-12 CEST (UTC+2)

Agenda

09:00 to 11:20 Presentations

09:00-09:15	Welcome & Introduction + feedback on Geopolymers from earlier webinar (Erika Holt, VTT)
09:15-09:30	Geopolymers: An innovative class of materials (David Lambertin, CEA)
09:30-09:55	Direct PREDIS Connections to Geopolymers: -WP2 WAC (Lumír Nachmilner, CV REZ) -WP4 Metallic Waste (Abdesselam Abdelouas, IMT) -WP5 Liquid Organic Waste (Maxime Fournier, CEA) -WP6 Solid Organic Waste (Thierry Mennecart, SCK CEN)
09:55-10:15	Durability of Geopolymers (Prof. Martin Cyr, LMDC)
10:15-10:20	break
10:20-10:40	Iron-Rich Binders from Bauxite Residue (Tobias Hertel, KU Leuven)
10:40-10:55	Use of Geopolymers in the Disposal of LLW/ILW in the Czech Republic (Václava Havlová, ÚJV)
10:55-11:15	Regulatory Issues and Geopolymers: approaches in non-nuclear sectors (John Provis, University of Sheffield)
11:15-11:20	break

11:20 to 11:50 Breakout Room Discussions

- what are the barriers to wider implementation of geopolymers in RWM?
- where can PREDIS potentially further contribute to developments in geopolymers?
- can PREDIS serve as a test bed for verification/demonstration of additional geopolymer processes which are close to deployment?

11:50 to 12:00 Close

11:45-12:00	Feedback from breakout rooms / Summary and Conclusions
12:00	Adjourn

This project has received funding from the Euratom research and training programme 2019-2020 under grant agreement No 945098.

Appendix 2. Live-Polling Results

Why did you register for this webinar?

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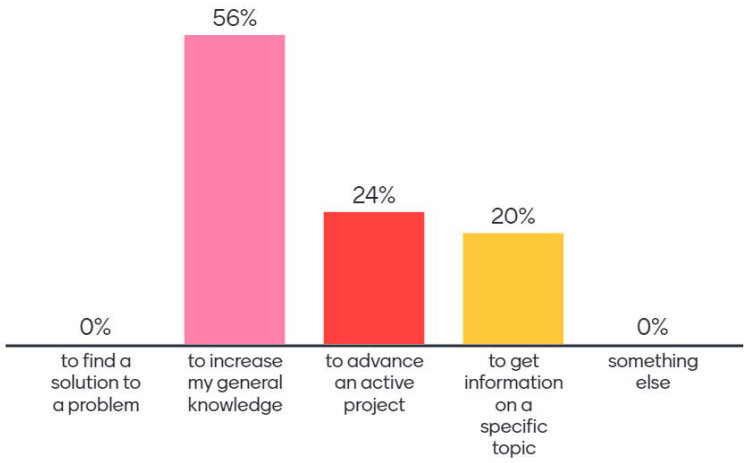

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For which waste streams would geopolymer solidification be most suitable/beneficial?

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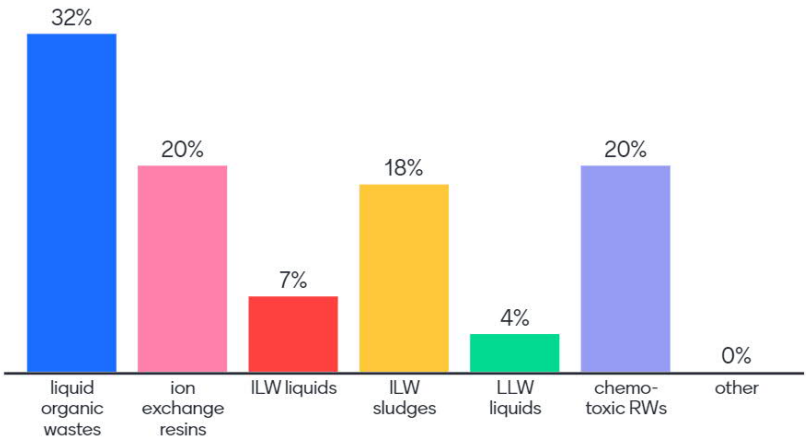

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