PREDIS

Deliverable 5.6
Dissemination report on the use of geopolymer matrices for the immobilization of liquid radioactive waste

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Dissemination level Public

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Abstract

PREDIS Work Package 5 (WP5) is focused on the direct conditioning consisting in encapsulating the RLOW in a solid matrix to obtain a composite material (conditioning and stabilizing the organic liquid) which can constitute the base of a radioactive waste package capable to fulfil the requirements of disposal facilities.

Particularly, the content of this deliverable aims to provide a report on the dissemination activities undertaken by WP5 including publications produced and participation in relevant conferences of the sector. The content of which focused mainly on the approaches, innovations, and technologies for “Direct conditioning of RLOW in geopolymers”.

The aim of dissemination activities was to gain awareness on the use of geopolymer matrices for the immobilization of liquid radioactive waste, with also a focus on the potential future developments, and to spread results to the largest possible audience outside the consortium.

This deliverable provides a description of the dissemination activities carried out by WP5, to ensure the visibility of the project and its results, and the accessibility to the information developed by WP5, which consisted of the confirmation of existing knowledge, and the generation and spreading of new knowledge.

The deliverable D5.6 is structured in different sections according to the type and form of dissemination (publications, presentations, social media). The list of journals (open-access (OA) to ensure fast access and high-quality peer reviews) publications, presentations on scientific conferences, such as public speaking and poster presentations will be part of this document. Moreover, metadata that includes a persistent identifier (such as the Digital Object Identifier, DOI) has been added for each publication to allow easy and persistent reference.

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1 Introduction

The PREDIS project (predisposal management of radioactive waste) is a research and innovation action granted by the European Atomic Energy Community which targets the development and improvement of activities for the characterisation, processing, storage, and acceptance of intermediate- and low-level (ILW/LLW) radioactive waste streams. It targets innovation and break-through technologies for safer, more efficient, cost-effective, and environmentally friendly handling of ILW/LLW radioactive wastes. Particularly, Work Package 5 “Innovations in liquid organic waste treatment and conditioning” (WP5) of the PREDIS project is focused on geopolymer matrices for the immobilization of liquid radioactive waste.

WP5 is concerned with the direct conditioning of radioactive RLOW encapsulated into a solid matrix to obtain a composite material (conditioning and stabilizing the organic liquid) constituting the base of a radioactive waste package that could fulfil the requirements of disposal facilities. The aim of gaining awareness on the use of geopolymer matrices for the immobilization of liquid and solid radioactive waste, with also a focus on the potential future developments, was the key objective of Task 5.6 and of this deliverable D5.6 content.

Therefore, the dissemination of the main findings and research results by sharing them with the scientific community and interested parties, as e.g. the end-users, was carried out by:

- Disseminating technical and scientific advances via reporting and open-access publications
- Providing documentation to be used as training and guidance
- Participating in conferences and networking occasions to raise awareness of achievements.

It is important to remark that the technical description of the methodology, procedures and results obtained from the activities performed in WP5 are out of the scope of this deliverable, the intent of which is to provide a broad overview of the specific dissemination materials, e.g. peer-reviewed scientific publications relating to the project's results (including not only journal articles but also conference proceedings and long-text publications such as monographs, book chapters, edited volumes, etc.) aimed at describing innovations and technologies specific to direct conditioning of RLOW in geopolymers and raising awareness of achievements.

The following sections summarise only the dissemination activities, consisting of journal publications, deliverables and milestones, publications, and presentations in targeted conferences. They are directed to scientists and others who can learn from the results. Figure 1Figure 1 shows the distribution of the different types of dissemination employed in WP5 (this distribution refers to the dissemination activities updated in May 2024).

The exploitation activities in the perspective of practical use, referring mainly to the WP5 results/outputs described in the deliverable D5.3, are not the subject of this deliverable.

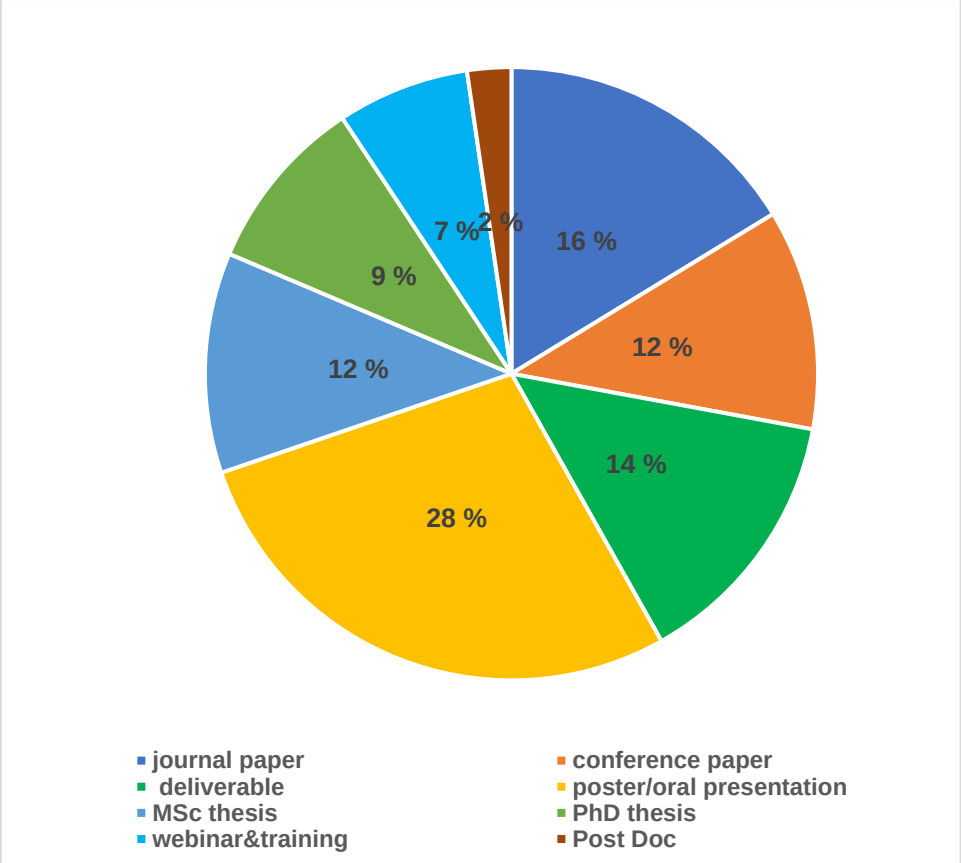

Figure 1- Dissemination activities.

2 Dissemination through journal publications

Dissemination strategy is focused on the open science for sharing of knowledge, results, and tools as early and widely as possible.

The following Table 1Table 1 lists the peer-reviewed journal and conference (conference proceedings) publications: each publication provides author(s) name, title of paper, citation including persistent identifiers (e.g., DOI, Handle). Keywords and the area of interest are provided to streamline dissemination actions. The bibliographic metadata provided in Table 1 allows easy identification of the deposited publication.

Table 1: Journal publications. The open access publications have the "journal" box in green.

Authors	Title	Journal	DOI	Publication Year	Area of interest	Keywords
R. Lo Frano, V. Dolin, S.A. Cancemi	The influence of tritium behaviour on spent fuel pool concrete	Progress in Nuclear Energy	https://doi.org/10.1016/j.pnucene.2024.105053	2024	WM & Nuclear, Material	Tritium; Spent fuel; Concrete damage; Filtration; Wet storage facility; Tritium release
T. N. Nguyen, et al.	Microstructure, water permeability and micromechanical properties of alkali activated slag subjected to accelerated leaching	Materials & Design	https://doi.org/10.1016/j.matdes.2024.112706	2024	WM & Nuclear, Material, Chemical	Alkali activated slag; Leaching resistance; Microstructure; Permeability; Micromechanical property
T. N. Nguyen, et al.	Microstructure and transport properties of metakaolin-based geopolymers subjected to accelerated leaching	Construction and Building Materials	https://doi.org/10.1016/j.conbuildmat.2024.136225	2024	WM & Nuclear, Materials	Metakaolin-based geopolymer; Accelerated leaching; Microstructure transport properties; Permeability Diffusion
E. Mossini, et al.	Pre-impregnation approach to encapsulate radioactive liquid organic waste in geopolymer	Journal of Nuclear Materials	https://doi.org/10.1016/j.jnucmat.2023.154608	2023	WM & Nuclear, Materials Radio-Chemistry	Radioactive liquid organic waste; Recycled polyurethane; Pre-impregnation Geopolymer; Waste acceptance criteria
L. Frederickx, T. N. Nguyen, Q. T. Phung	Strength and Microstructure Characteristics of Metakaolin-Based Geopolymer Mortars with High Water-to-Binder Ratios	Sustainability	https://doi.org/10.3390/su14063141	2022	WM & Nuclear, Materials (Radio)Chemistry	geopolymer; metakaolin; mortar; microstructure; mineralogy
T.N. Nguyen, Q.T. Phung, Z. Yu, et al.	Alteration in molecular structure of alkali activated slag with various water to binder ratios under accelerated carbonation.	Scientific Reports	https://doi.org/10.1038/s41598-022-09491-4	2022	WM & Nuclear, Materials (Radio)Chemistry	-
C. Reeb, et al.	Incorporation of organic liquids into geopolymer materials - A review of processing, properties and applications.	Ceramics International	https://doi.org/10.1016/j.ceramint.2020.11.239	2021	WM & Nuclear, Materials, Chemistry	Geopolymers; Organic liquid; Incorporation Emulsion; Impregnation

3 Dissemination through public deliverables

The public deliverables of the WP5 PREDIS project intended to disseminate the main technical project's outputs are:

- D5.2 Technical report "Synthesis of formulation process studies results for direct conditioning of liquid organic waste"
- D5.3 Technical report "Synthesis of conditioning matrix performances studies results for direct conditioning of liquid organic waste"
- D5.4 Disposability assessment report for direct conditioning of liquid organic waste
- D5.5 "Direct conditioning of liquid organic waste route" Basic Design
- D5.6 Dissemination report "Use of geopolymer matrices for the immobilization of liquid and solid radioactive wastes"
- D5.7 Final report on WP5 interactions with stakeholders/end users.

Deliverables with public dissemination level are published in the "Publications and reports" section of the PREDIS project website (see the link: https://predis-h2020.eu/dissemination/ for more details).

4 Dissemination through webinars and trainings

In the frame of WP5 a webinar on "Innovations in liquid organic waste treatment and conditioning" was held on 30.3.2021 to describe the "Radioactive Liquid Organic Waste (RLOW) – Which Wastes Are These?" (see the link: https://predis-h2020.eu/wp-content/uploads/2021/03/02_S.-Wickham-RLOW.pdf) and illustrates also the "World Practices for geopolymers" (see the link: https://predis-h2020.eu/wp-content/uploads/2021/03/03_J.-Provis-Geopolymers-and-challenges.pdf). Flash talks were also arranged on these subjects.

A free training module on pre-disposal waste management, provided within the EURAD training day, 14.9.2020, is available at the link: https://www.youtube.com/playlist?list=PLahXOQn-bremYbN7GA8H9YN_m8AlVHCz1.

An overview of the project, with emphasis on the potential for cooperation with the EURAD project was done in the form of a "Lunch and Learn" session for stakeholders, 28.10.2020. It is available at the link: https://www.youtube.com/playlist?list=PLahXOQn-bremN911IEn0w8yAzQyuUR3ky.

For interactive dissemination, Consortium partners participated in several events, in person and remotely, such as international scientifically relevant Conferences, Workshops, Meetings and Symposia that represented an excellent opportunity to share the results with scientific community and industry experts and, therefore, to achieve an effective dissemination of the project.

These events can be grouped into:

a. Project events (specifically the annual PREDIS conference/workshop).
b. Participation in external events

As for the point a. above, these are the following internal workshops:

- 2024 PREDIS Final conference, Avignon, France, 3rd-7th June
- 2023 PREDIS Annual Meeting, Mechelen, Belgium, 23rd-26th May
- 2022 PREDIS Annual Meeting, Espoo, Finland, 25th-27th April
- 2021 PREDIS Annual Meeting, 4th-6th May
- 2020 PREDIS Annual Meeting, 19th- 21st October
- 2023 WP5 Workshop, Prague, Czech Republic, 23rd-24th November
- 2022 WP5 Workshop, Rome, Italy, 29th-30th September
- 2021 WP5 Workshop, 26th-27th October.

As for the point b. above, these are presented below.

In particular, Table 2 summarises the conference attended in person with presentation and technical paper (published in the conference proceedings after a peer-review process). This table provides author(s) name, title of paper presented/ collected and published in the context of conference or workshop or symposium, citation including persistent identifiers (e.g., DOI, Handle), if present. Keywords and the area of interest are added to provide to streamline dissemination actions.

Table 2: Conference (with indication of proceedings paper). The open publications have the “Proceeding” box in green.

Authors	Title	Proceeding	DOI	Year	Area of interest	Keywords
F. Pancotti, et al.	Investigation, Development and Assessment of Innovative Direct Conditioning Solutions for Radioactive Liquid Organic Waste Within the PREDIS Project	ASME 2023 International Conference on Environmental Remediation and Radioactive Waste Management	https://doi.org/10.1115/ICEM2023-110253	2023	WM, Material, D/D&D	radioactive liquid organic waste; direct conditioning; geopolymers; alkali-activated materials
A. Sears, et al.	Direct conditioning of liquid organic radioactive waste into a geopolymer matrix	32nd International Conference Nuclear Energy for New Europe	https://www.djs.si/upload/nene/2023/proceedings/Contribution_517_final.pdf	2023		-
R. Lo Frano, S.A. Cancemi	Numerical Investigation of Cemented-Based Material to Be Used for Packaging System	ASME 2023 International Conference on Environmental Remediation and Radioactive Waste Management	https://doi.org/10.1115/ICEM2023-110093	2023	Waste Management; Material	Mechanical Characterization, RW Immobilization, Simulation, FEM, Safety
S. A. Cancemi, et al.	Preliminary Thermo-Mechanical Characterization of Cement-Based Materials for LLW Immobilization	ASME 2023 International Conference on Environmental Remediation and Radioactive Waste Management	https://doi.org/10.1115/ICEM2023-110086	2023	Waste Management; Material	Concrete, RW, Aging, Integrity, Failure
R. Lo Frano, et al.	Numerical Simulation Of Cemented RLOW For Packaging System	31st International Conference Nuclear Energy for New Europe- NENE2022	https://www.djs.si/nene2022/proceedings/htm/pdf/NENE2022_708.pdf	2022	Waste Management; Material	-

To complete and complement the list of events mentioned in the previous point b., we provide a list of the external events, e.g. conferences, workshops, and symposia, where only an oral presentation or poster was made to disseminate the main research-based findings and information of the WP5 activities. These also include some related to multiple or transversal WPs project. The name of the presenter(s), title of the presentation/poster are provided with indication of the place where the event took place.

1. E. Holt, M. Oksa, A. Banford, 2021. International cooperation on pre-disposal waste management innovation in the PREDIS project: Addressing technology gaps and common industrial challenges. PREDIS presentation within Euratom-focused panel discussion, IAEA radwaste conference, Vienna, 4.11.2021. https://predis-h2020.eu/wp-content/uploads/2021/11/IAEA-Conference_CN-294_E-poster_PREDIS_2021-11-01.pdf
2. E. Holt, M. Oksa, M. Nieminen, 2022. Predisposal conditioning, treatment, and performance assessment of radioactive waste streams. EURADWASTE'22 Conf. May 30-June 3, 2022, Lyon (FR). https://predis-h2020.eu/wp-content/uploads/2022/07/EURADWASTE22-HOLT-PREDIS-THERAMIN-overview.pdf
3. F. Galluccio, et al., 2022. Innovative Oxidative Treatment and Geopolymer Encapsulation of Spent Mixed Bed Ion Exchange Resins. EURADWASTE'22 Conf. May 30-June 3, 2022, Lyon (FR). https://predis-h2020.eu/wp-content/uploads/2022/07/EURADWASTE2022_GALLUCCIO-WP5-Encapsulation.pdf
4. K. Hamadache, et al., 2022. Innovations in liquid organic waste treatment and conditioning. EURADWASTE'22 Conf. May 30-June 3, 2022, Lyon (FR). https://predis-h2020.eu/wp-content/uploads/2022/07/EURADWASTE2022_Poster_PREDIS_WP5-Hamadache.pdf
5. F. Pancotti, et al., 2022. Development of formulations for direct conditioning of Radioactive Liquid Organic Wastes. EURADWASTE'22 Conf. May 30-June 3, 2022, Lyon (FR). https://predis-h2020.eu/wp-content/uploads/2022/07/EURADWASTE2022_Poster_PREDIS_WP5-Pancotti.pdf
6. J. McWilliams., 2022. Geopolymers cements for the immobilisation of radioactive liquid organic waste. 41st Cement & Concrete Science Conference, 12–13 September 2022 University of Leeds.https://pure.coventry.ac.uk/ws/portalfiles/portal/56293089/41ST_CEMENT_AND_CONCRETE_SCIENCE_CONFERENCE_EXTENDED_ABSTRACTS.pdf
7. I. Moschetti, E. Mossini, G. Magugliani, M. Giola, E. Macerata, L. Brambilla, C. Castiglioni, D. Vadivel, D. Dondi, D. Cori, M. Mariani, Innovative and green pre-impregnation solution for the disposal of radioactive liquid organic waste, 4th International Symposium on Cement-Based Materials for Nuclear Wastes – NUWCEM 2022, Avignon (F), 4 – 6 October 2022
8. E. Mossini, A. Santi, G. Magugliani, M. Giola, T. Briola, E. Macerata, D. Vadivel, D. Dondi, D. Cori, P. Lotti, G. D. Gatta, M. Mariani, Green solution for encapsulation of radioactive liquid organic waste in novel geopolymers. The Nuclear Materials Conference NuMat2022, 24–28 October 2022, Ghent (B)
9. R. Lo Frano, et al. Experimental thermal characterization of concrete to be used RLOW packaging system. Poster. The Nuclear Materials Conference 24–28 October 2022, Ghent, (B).
10. J. McWilliams, B. Walkley, J. L. Provis, 2023. Geopolymer cements for the immobilisation of radioactive liquid organic wastes. 16th International Congress on the Chemistry of Cement: Further Reduction of CO_2-Emissions and Circularity in the Cement and Concrete Industry, September 18-22, 2023, Bangkok, Thailand

11. J. McWilliams, et al., 2023. Geopolymer cements for the immobilisation of radioactive liquid organic wastes, EURAD 3rd Annual Meeting

12. I. Giboire, et al. 2023. Innovations in liquid organic waste treatment and conditioning. Waste Management Symposia 2023 Conference, 27.2 – 2.3.2023, Phoenix, Arizona, USA

5 Dissemination through M.Sc. and Ph.D. thesis

M.Sc. theses:

1. S. Colombo (Polimi), Radioactive liquid organic waste management by direct conditioning in innovative geopolymer matrix (Academic Year: 2020-2021);
2. I. Moschetti (Polimi), Development and Characterisation of Innovative Solutions for Management of Challenging Radioactive Liquid Organic Waste (Academic Year: 2020-2021);
3. M. Brini (Polimi), Radioactive liquid organic waste encapsulation: a comparative study of pre-emulsification and pre-impregnation approaches (Academic Year: 2021-2022);
4. C. Forconi (Polimi), Enabling radioactive liquid organic waste disposal by direct conditioning in novel geopolymers (Academic Year: 2022-2023);
5. A. Santi (Polimi), Improving the direct conditioning of low-viscosity radioactive liquid organic waste in geopolymers: a durability and robustness study (Academic Year: 2021-2022).
6. M. Alvarez-Gomez (IMT Atlantique), Simulation of radiological properties (on-going, Academic Year: 2023-2024).

Ph.D. theses:

1. T. N. Nguyen, (SCK-CEN and IRSN) Physico-chemical evolution of geopolymers in contact with aggressive environments. 2024. 284 p. (https://lirias.kuleuven.be/4127087&lang=en).
2. S. Koubeissy (ECL) Durability of geopolymer matrices subjected to carbonation and leaching: application for the encapsulation of radioactive liquid organic wastes. 2024
3. J. Mc Williams (USFD) Developing geopolymer cements for the immobilisation for the radioactive liquid organic waste (ongoing)
4. A. Santi (POLIMI) Development of pre-disposal solutions for managing challenging radioactive waste (ongoing)

Post Doc activity:

1. A. Hasnaoui (CEA) Conditioning of organic liquids in geopolymer matrices (ongoing)

6 Summary

In this report, the dissemination of the main findings and research results from WP5 shared with the scientific community and interested parties has been described.

During the 4 years of the project, about 43 dissemination activities were conducted between 2020 and 2024 for WP5 “Innovations in liquid organic waste treatment and conditioning” alone (excluding dissemination activities related to multiple or transversal WPs of the PREDIS project).

The dissemination of technical and scientific advances via reporting and open-access publications represents 65.12 % of the overall activities.

The total publications as of June 10, 2024, are 20[1]. This number is far higher than the Key Performance Indicator defined for WP5 at the beginning of the project, which specifically expected 8 publications. The key performance related to the number of PhD theses supported expected 3 PhD students full time and 1 PhD common with WP4/WP6 can be similarly considered achieved.

This is to show the excellent performance of WP5 in terms of dissemination activities. Furthermore, a special issue in the journal *Nuclear Engineering and Design* (see the link: https://www.sciencedirect.com/journal/nuclear-engineering-and-design/about/call-for-papers) is co-edited by WP5 partners and will further enhance the dissemination activities.

Moreover, participation in additional upcoming conferences and networking will allow WP5 to raise awareness of achievements.

Based on the described activities, it is possible to say that the publications and deliverables produced in the WP5 PREDIS project confirm and ensure that the objectives of this work package are being met in a timely and efficient manner.

[1] This value includes journal papers, conference papers, public WP5 deliverables and PhD published thesis.