TRANSFERRING KNOWLEDGE OF NEW LILW PRE-DISPOSAL PRACTICES VIA CASE STUDIES FROM THE EURATOM PREDIS PROJECT

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Abstract

Pre-disposal of Radioactive Waste Management (PREDIS, 2020-2024) is a collaborative project funded by Euratom which focuses on low- and intermediate-level waste (LILW) streams. The PREDIS project of 47 expert organisations from 17 European countries strives to bring innovation and more accessible technologies to the community, directly impacting the Member States' practices in holistic radioactive waste management. Case Studies highlighting the PREDIS research outcomes as a form of Knowledge Management (KM) activities have been developed to preserve and transfer information arising from the collaborative activities. The Case Studies aim to capture knowledge and illustrate potential and delivered impacts on new low- and intermediate level waste (LILW) pre-disposal practices that were developed during the project. The paper explains how the Case Studies were developed, including the reasons for selecting the topics and evaluating the impacts. It discusses how the Case Studies can be used as a form of easy-to-read guidance for stakeholders on technologies and methodologies that can be implemented for LILW pre-disposal practices by providing examples on selected Case Studies. The Case Studies are also planned to be embedded to the IAEA Wiki and thus the KM platform is discussed from the PREDIS point of view.

1. INTRODUCTION

PREDIS is a large collaborative project within the Euratom research and training programme aimed at developing and implementing improved predisposal treatment of radioactive waste streams. The work focuses on Low and Intermediate Level Waste (LILW) radioactive waste streams thus excluding spent nuclear fuel. LILW predisposal activities includes material characterisation, processing, treatment, storage and acceptance of waste streams for final disposal, all of which are somewhat addressed in the project through various tasks to find new innovation and solutions [1] . It is important that the pre-disposal waste issues utilize a holistic approach within the nuclear back-end management, supporting the waste hierarchy of reducing waste streams towards geological disposal. This linkage between sustainable practices needs arising from decommissioning as well as final disposal is highlighted via the recently developed PREDIS Strategic Research Agenda, in collaboration with the European Joint Programme on Radioactive Waste Management, EURAD. In order to continue to deploy new nuclear

solutions, the best practices and knowledge sharing on the waste management issues is also of paramount importance.

PREDIS identified that it was critical to communicate the project results and their impact efficiently to the project stakeholders, including the end-users group (EUG). The EUG of PREDIS consists of nuclear power plant operators and research reactor owners as radioactive waste producers and waste management organisations (WMOs), and the project has aimed to answer their priorities regarding safer, more efficient and economic handling of LILW. Though LILW pre-disposal and disposal management has been in practice for decades in many countries, there are still new innovations and technologies that can be implemented, yet these need to be demonstrated before acceptance by regulators and other stakeholders. In addition, sharing the project findings to interested parties outside of the project was deemed equally important. To reach the external parties, PREDIS Case Studies (CS) outlining the conducted research and its impacts towards practice were developed. The paper summarises the methodology and research of the CS work in PREDIS. It also discusses the benefits of sharing knowledge through CSs.

Case Studies bridge theory and practice by explaining the former with its real-world experiences and lessons learned. In this way the CS contribute to understanding the topics and their impacts, for example by general practitioners, decision makers and even non-experts, and guide them towards better practices or more detailed information, and future research collaboration. In technological research, the CS typically describe a practical application of a new methodology or technology and learnings from the research and development process. The CS can also aim to influence decision makers to invest in the emerging technologies or guide them to update older, possibly outdated practices with newer, more effective ones. Case Studies are already widely integrated to the IAEA's CONNECT platform Wiki of decommissioning, to provide examples of best practices [2].

In the nuclear industry, the number of different technologies is vast, and especially for new countries considering adopting nuclear power, it can be overwhelmingly difficult to discover the most effective practices in use and decide on the most appropriate technologies for their waste inventory. At the same time, new, more cost-effective technologies are constantly being developed which benefit the other end-users as well as creating the need to share these new findings. CS are one option to answer these issues. The existing IAEA CS are mostly focused on descriptions of decommissioning of different nuclear power plants and remediation activities of various contaminated sites. Their contents vary, but most have information on the legal framework, implementation of technologies, technical issues, lessons learned, and costing aspects written in a concise, non-technical language.

CS were also created in the PREDIS project to disseminate the predisposal waste management project results to the industry and end-users and to other interested parties outside of the project team. The aim of this paper is to describe the contents of the PREDIS CS, their development as well as the process of selecting the topics. It also elaborates the benefit of CS by sharing some examples.

2. PREDIS CASE STUDIES

The premise for generating the PREDIS Case Studies as part of the project's dissemination and knowledge capture arose from the existing IAEA Case Studies and the target to generate greater content that can reach a wider audience beyond the traditional project technical outcome reports. They were seen as an effective way to communicate Radioactive Waste Management (RWM) practices in a non-technical language and without a commercial pitching perspective. For PREDIS, the CS could be used to communicate best practices in predisposal waste management that have been adopted by the project members or the end-user group. The eventual goal is to append the IAEA CS catalogue with the PREDIS CS and potentially complimenting their other learning modules. This way the best practices would be more accessible for non-project members such as the industry or newcomers to the nuclear field (both individuals and countries).

The PREDIS CS act as the simplest tier of a three-tier dissemination system, where each tier increases in complexity of technical details. The Case Studies explain technology goals and impacts without going into detail on how the research behind the methodology has been conducted or on any assessment protocols that have been carried out to determine the technology's impact. Instead, they direct the interested reader to more information either towards the second tier, the Value Assessment, or the third tier, the Scientific Publications of the project. These second and third tier documents are much more elaborate and provide further context for decision making,

including for instance quantitative economical and life cycle sustainability values, and long-term performance models as needed for a safety assessment.

The CS development started by creating a CS template ensuring all CS would be created with a similar intent and content. This way the overall structure could be repeated from one topic to another across all of the project tasks, streamlining the creation process, while still ensuring the core information is captured in each CS.

Each CS focuses on one specific technical topic with a target length of a two to three pages. They describe the adopted technology or methodology without going into the technical details and instead direct to the academic publications containing the details. The aim is to keep the length short to attract even the busiest audience, but still extensive enough to convey useful information. Another instruction in the template is that the CS should not be commercial in nature and instead capture the independent experts' point of view. This is to reinforce the impartial image of the research done on a specific technology, when working in a field in which trust is important in maintaining a positive public opinion.

The CS template consists of four main sections, and three sections of additional information. The first main section, *Challenge to solve*, outlines a key problem in predisposal waste management that needs addressing. The problem can be either existing beforehand and having been identified during the PREDIS project though engagement with stakeholders and documented in project workshop proceedings [3], or the problem could be totally a new challenge arising from new methodologies developed within PREDIS. The next section, *Approach taken*, describes in a non-technical manner what actions have been taken to solve the challenge. This could include description of a new methodology, or other development work that has been carried out to increase the technology readiness level from concept, through modelling, then small-scale and then full-scale demonstrations. The third main section, *Innovation*, aims to emphasise what, in the specific approach taken, is new compared to traditional or established practices in RWM. Finally, in *Impact towards practice*, the emphasis is on identifying and presenting key performance indicators such as improved safety, cost, time management, decrease in materials consumed, and free release of materials that support the waste hierarchy.

For each CS, a specific topic was selected based on topics proposed by the leaders of the technical work packages, and key experts of the project were contacted for an interview (more on topic selection in the next section). The authors of the Case Studies interviewed the experts to both decrease the effort needed by the experts, making it more likely that they would have time to participate, and to maintain a unified voice throughout the Case Studies. After the interviews, the CS was drafted by the interviewers, followed by revisions by the technical experts and the WP leaders. The Case Studies are reviewed by End Users who are utilizing the PREDIS outcomes in practice and have been guiding the project from planning through implementation.

For the impact towards practice section, the results from Value Assessment (VA) work were also included. In VA, outcomes of PREDIS main actions are evaluated based on their benefits, strengths, weaknesses and opportunities by comparing them to pre-existing baselines. The performance evaluation can be done on criteria such as waste loading, technology readiness level, while the baselines, such as cementation of waste, are practices that are common in the nuclear sector. The assessment is performed for different waste types and selected treatment technologies and will be reported as park of the final outcomes of PREDIS, such as for treatment of solid organic wastes [4]. The scope and assessment methodology are selected next so that performance criteria (such as durability, cost and operational safety) are clearly defined. Finally, the assessment is performed for scenarios involving different treatment technologies and wastes.

For the CS, interesting results from the VA are for example those related to the effects of the adopted technology on the total amount of waste needed to be disposed, or improvement of the mechanical strength of an immobilised waste. In conclusion, the VA results help with quantifying the value of the research for the end-users and industry.

Finally, the aim is to involve the end-users and industry during the PREDIS final conference in early June 2024. The target is to obtain statements from them that indicate how the research output on new or improved technologies has already been applied by them or to find out whether they are considering applying the results, if they have not yet done so. This would emphasise the impact that the CS have had for the end-users and industry.

3. CASE STUDY TOPIC SELECTION

Each PREDIS technical work package (WP) leader proposed a few topics that would be potentially interesting and suitable for a Case Study. The proposed topics focused on successful research that had results that

could be impactful for the end-users. Out of these suggestions, to date, four have been selected to be presented as a Case Study. The topics were prioritized based on the input of the WP leaders, availability of experts and interviewers, and on the relevance to the Value Assessment work. The proposed and selected topics are presented in Table 0-1. The topics that were not selected for Case Studies at the time of the writing of this paper could still be selected before the PREDIS project ends in autumn 2024.

Table 0-1: Proposed topics for the case studies with the selected ones being bolded.

Work Package	Topics
WP4 – Innovations in metallic material treatment and conditioning	
	1) Chemical decontamination of metallic waste
	2) Conditioning of reactive metallic waste using Magnesium Phosphate Cement
	3) Non-destructive gamma spectrometry methodology for metallic waste characterisation
WP5 – Innovations in liquid organic waste treatment and conditioning	
	1) Radioactive Liquid Organic Waste experiments
	2) Scale-up experiments
WP6 – Innovations in solid organic waste treatment and conditioning	
	1) Molten Salt Oxidation used for the treatment of Radioactive Liquid Organic Waste
	2) Wet Oxidation Route used for the destruction of dissolved organic contaminants
	3) Geopolymer immobilisation
	4) Cement based materials immobilisation
	5) New technique: Molten glass coating
	6) Compaction assisted by thermal treatment
WP7 – Innovations in cemented waste handling and pre-disposal storage	
	1) Approval for using recycled materials in cemented waste
	2) Monitoring waste packages with small affordable sensors
	3) Monitoring packages with limited access without having to move them

4. CASE STUDY EXAMPLE

In this section, the PREDIS CS on waste immobilisation using geopolymers instead of a cement-binder matrix is summarized. The topic has been studied by VTT Technical Research Centre of Finland in PREDIS WP6 - Innovations in solid organic waste treatment and conditioning. The full text of the Case Study will be published during 2024 (see [1]), but the main aspects are summarised here.

The CS addressed the issues of the use of traditional binders used in nuclear waste immobilisation and how they could be replaced with geopolymers. Traditional binders such as cement and bitumen are conventional and well-proven technologies already used in practice and accepted by regulators and waste management organizations for final disposal. However, geopolymers have been proposed as a more sustainable alternative, as they can have locally better availability than traditional binders and are also more sustainable through reduced emissions associated with traditional cement production. In addition, thermal treatment of ion-exchange resins can lead to significant volume reductions in disposed waste yet having a higher concentration of radionuclides that need binding prior to disposal. The CS explains the new methodology of gasified LILW resin waste immobilisation with a geopolymer binder and its comparison to immobilisation with a cement binder. The main innovation of the approach was built upon the work carried out in a previous project[5] The CS also elaborates that the main impact with thermal treatment and geopolymer immobilisation was the significant volume reduction and the improved disposability of the final product. This could lead to fewer waste packages and thus less space in a repository is needed, allowing for longer-term immobilization of operational waste with existing repository space. The waste immobilised in geopolymers did well in comparison to the traditional cement-based concrete, as they had better mechanical properties, decreased leaching, improved disposability, and fewer durability concerns for long-term safety.

For the overall process of generating CS as a form of knowledge capture, the most significant challenges encountered while producing a CS included the balancing the level of detail of the summarised research work so

that sufficient understanding of the topic was provided without overcomplicating the text. Other challenges included limiting the use of professional jargon and the final quantification of impacts while the research was still ongoing. Overall, the process of developing a CS largely depended on and was influenced by researchers' availability, the different stages of research on the various topics, timely evaluation of impacts and coordination with other project outputs.

5. CONCLUSIONS

This paper explained how PREDIS Case Studies were developed, what they contain and what are their topics. At the time of this paper, four Case Study topics have been selected from the technical work packages of the project and will be ready by June 2024. These CS are in in different stages of the writing process and are still integrating the end-user contribution, scheduled for the next months.

The CS creation process, including the CS template and interviews with experts is an effective way to create dissemination outputs with a unified language and structure. This ensures that each CS is introducing a defined problem and an approach taken to address it as well as highlighting the innovation and the impacts of the approach. However, some aspects, such as expert availability, and the high level of technical detail in the source information were challenges encountered during the writing process.

Together with the Value Assessment results and technical deliverables of PREDIS, the CS create a system consisting of three dissemination tiers. The CS act as the first tier, giving an easy-to-read summary of some of the project's technical results that have made predisposal practices more efficient. They highlight the benefits of the implementation of new practices for various stakeholder groups. Presented for a wider audience, the CS however lack the technical details or the thorough assessment of the reasons the implemented technology or methodology was impactful. Instead, they direct a reader to the second tier of Value Assessment work or the third tier consisting of all the peer reviewed scientific outcomes of the project. Thus, PREDIS CS allow to disseminate best practices from the project to the end-user group, industry and nuclear sector stakeholders. The CS also make science more accessible to larger audience, as an open access easy to approach source of information as part of the holistic knowledge management activities in the project.

The next steps of the PREDIS CS include finalizing the case studies on at least the selected topics. All the topics require the end-user contribution, which will present the value that they have gained from the CS. The final aim is to integrate the CS within the IAEA Wiki and the Knowledge Management platforms of PREDIS and EURAD, from where they can be accessible to a wider audience of stakeholders of the radioactive waste sector worldwide.

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REFERENCES

[1] PREDIS project web page, general overview https://predis-h2020.eu/

[2] IAEA, Category: Case studies (2023), https://nucleus.iaea.org/sites/connect/IDNpublic/Pages/IDN-Wiki-Introduction.aspx

[3] PREDIS Proceedings of May Workshop 2023, Deliverable D1.5, 128 p. https://predis-h2020.eu/wp-content/uploads/2023/10/PREDIS_D1.5-Proceedings-Annual-WS-2023_vFinal_29.9.2023.pdf

[4] PREDIS Deliverable D6.3 Economic, Environmental and Disposability Impacts of Novel Treatment Report, summer 2024.

[5] VEHMAS, T., MYLLYKYLÄ, E., NIEMINEN, M., LAATIKAINEN-LUNTAMA, J., LEIVO, M., & OLIN, M. Geopolymerisation of gasified ion-exchange resins, mechanical properties and short-term leaching studies, IOP Conference Series: Materials Science and Engineering, 818, (2020)