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Research

Investigation of the limits of detection for specific radionuclides in soil from the European Spallation Source (ESS) using radiometric and mass spectrometric methods

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Author: Guillaume Pédehontaa-Hiaa [1,2], Robert Frost [2,3], Vytenis Barkauskas [4], Kristina Eriksson Stenström [2], Mikael Elfman [2], Christian Bernhardsson [1], Christopher Rääf [1]

[1] Medical Radiation Physics Malmö, Department of Translational Medicine, Lund University, Sweden

[2] Division of Nuclear Physics, Department of Physics, Lund University, Sweden

[3] Division of Applied Nuclear Physics, Department of Physics & Astronomy, Uppsala University, Sweden

[4] Centre for Physical Sciences and Technology, Vilnius, Lithuania

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SSM perspective

Background

In Lund, the construction of the European Spallation Source (ESS) research facility is underway and the facility is also undergoing a stepwise licensing procedure in accordance with relevant legal requirements. At ESS, neutrons will be produced by spallation when high-energy protons from a linear accelerator hit a rotating tungsten beam target. The neutrons released from the radiation target will be used for various scientific experiments.

The Radiation Safety Authority (SSM) announced in 2021 funds for research to develop measurement methods for the specific radionuclides that may occur in the event of a release beyond expected operation from the ESS facility. The purpose of the call was to enable further development of useful measurement methods for these specific radionuclides and especially with regard to the specific radionuclides that have been shown to dominate the dose contribution to the public.

In the report Underlag till beredskapsplanering kring ESS (SSM 2018:22) it appears that Gd-148, W-187, Hf-172, Ta-182 and Hf-178n are the radionuclides that contribute the most to the effective dose to the public in the event that considered as dimensioning for emergency planning around the facility. Applicable measurement methods are missing for the majority of these nuclides today. Therefore, it is of crucial importance for radiation protection to have good measurement methods for exposure situations such as in a radiological emergency.

Investigations have already been conducted on the methods to assess releases of 148Gd from the ESS facility into the environment (Identifying radiologically important ESS-specific radionuclides and relevant detection methods 2020, and Region-specific radioecological evaluation of accidental releases of radionuclides from ESS, SSM2019-1010). The present report is a continuation of this work and extends it to the assessment of other radionuclides of concern. In this project, literature reviews and experimental studies were performed for two different techniques (ICP-MS and Gamma spectroscopy) in order to estimate their limits of detection for the ESS-specific radionuclides at trace levels in soil.

Results

This study provides information about the concentration of Tungsten (W), Hafnium (Hf) and Tantal (Ta) in the ESS soil and recommendations on the most appropriate sample preparation and measurement technique to assess contamination by these elements. The current levels of W, Hf and Ta measured in this study are in agreement with the estimated values from previous geological surveys. ICP-MS showed low limits of detection for W, Hf and Ta and is thus an appropriate technique for environmental monitoring. However, the three metals are difficult to extract from soil and require the use of specific sample preparation methods (based on hydrofluoric acid for example). The transfer of stable W, Hf and Ta from soil to plant is poorly known and only a handful of publications can be found that are relevant to the plants grown around the ESS. The transfer of the radioisotopes of W, Hf and Ta in particular to animals (and man) is even less studied. However, the existing articles indicate a fast excretion of radio-W and radio-Ta while the excretion is slow for radio-Hf.

The Minimum Detectable Activity (MDA) for gamma emitter released from the ESS facility will depend not only on the performances of the detection equipment but also on the composition of tungsten target at the time of the release.
The determination of limits of detection of ESS related gamma emitters was performed using a strategy based on simulation of spectra. Semi-synthetic gamma spectra were obtained by combining real soil measurements with simulated data for mixtures of ESS radionuclides using the software Nucleonica. The simulation of 187W spectra was used as a proof of concept for the method. With this approach, it is possible to estimate limits of detection by gamma spectroscopy for a given target composition. The limits of detection of four relevant radionuclides were successfully determined for two different compositions of the ESS target and at three different activity concentrations in soil.

Relevance

Knowledge of measurement methods and their application for the specific radionuclides produced at ESS is of vital interest as it increases the possibility of producing better data in the event beyond expected operation. This knowledge can also be useful for the operator and other similar activities in the world. This research is also a contribution to strengthening the national competence in radiation safety, which is in line with the needs identified in the government mission "The basis for a long-term competence supply in the field of radiation safety" (SSM2017-134-23). SSM intends to use the results as much as possible within permit review and supervision and disseminate the information to authorities that regulate similar activities.

Need for further research

Additional research is needed to estimate transfer factors of W, Hf and Ta from soil to the plants cultivated around ESS that can enter the human food chain and to build transfer models based on these results. The existing data are scarce or incomplete. The existing knowledge regarding their transfer to animal and man is limited to the studies described in the publication 151 by ICRP but this type of research is difficult to perform, in particular when using radionuclides. A combination of additional experimental data and modelling of the transfer of these metals in the ESS environment would help to understand the risks caused to human health by the spread of radioactive target material in the environment.

Additional work may be needed to extend the work on limits of detection to more ESS-specific gamma emitting radionuclides including the metastable ones and to determine the most relevant accident scenarios where this method should be applied.

The MDAs for gamma emitter produced by the ESS will depend not only on the performances of the detection equipment but also on the composition of tungsten target at the time of the release and further studies taking this in consideration is needed.

Project information

Kontaktperson SSM: **Karin Aquilonius**
Referens: SSM2021-787/ 4530523

The Swedish Radiation Safety Authority (SSM) works proactively and preventively with nuclear safety, radiation protection, nuclear security, and nuclear non-proliferation to protect people and the environment from the harmful effects of radiation, now and in the future.

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Strålsäkerhetsmyndigheten
SE-171 16 Stockholm
+46 (0) 8-799 40 00
www.stralsakerhetsmyndigheten.se
registrator@ssm.se

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