Investigation of the radioactive inventory in the reactor pressure vessel of a nuclear power plant - A key for efficient nuclear waste disposal

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1 Introduction

Nuclear power plants NPPs have been considered an important source of neutral CO_2 energy in Europe since a long time. [1] However, following the Fukushima accident in 2011, the German Bundestag issued a law to terminate the operation of the NPPs in Germany by the end of 2022. Therefore, a comprehensive plan that includes environmental assessment as well as radiological protection needs to be followed. The decommissioned Greifswald NPP represents the first generation of the Russian WWER-440 type. [2] Our work is mainly focused on the dismantled units of reactor pressure vessel RPV of the NPP, since it is considered as the main shielding barrier of the radioactive fuel to the outer environment.[1] For this purpose, the microstructural features and the radioactive inventory of the RPV steel shielding material were investigated. Surface analysis experiments, based on scanning electron microscopy / energy dispersive X-ray spectroscopy SEM / EDX were performed on both un-irradiated and irradiated samples, to understand the impact of the neutron fluencies on the RPV steel shielding material during the long-term operation. Gamma spectrometry measurements were performed for the analysis of gamma emitting radionuclides RNs in a nondestructive measurements of the irradiated samples. The characterisation of the beta emitting RNs can be assessed by destructive analysis DA, that have to be separated and purified from interferences, followed by characterisation of their activities and quantities. Therefore radioanalytical procedures for the separation of ^{63}Ni, ^{60}Co, ^{55}Fe were developed. In addition to that, oxidizing combustion method has been investigated to determine ^{14}C using a commercial sample oxidiser.

2 Experimental

2.1 Sample preparation

Trepans were extracted from the walls of the RPV at different positions from the reactor core. Analysis was performed on both un-irradiated and irradiated samples of the steel RPV shielding material. The trepans were sliced into specimens (10×10×1) mm sections and underwent polishing process for the imaging methods.

2.2 Radiochemical, microscopic, and spectroscopic Methods

SEM measurements revealed the microstructural features of the irradiated steel samples related to their chemical composition. In comparison of the irradiated samples to their un-irradiated analogues, results revealed the increase of dark cluster inclusions and the distribution of white precipitates as shown in figure 1. EDX experiments showed the presence of Mn inclusions in the dark clusters, and the presence of Mo precipitates as white segregated particles.

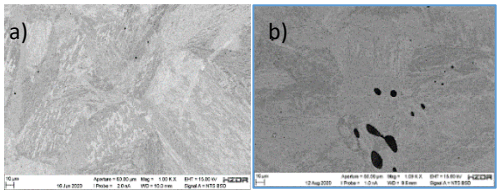

Fig. 1. SEM imaging measurements of both(a) un-irradiated and (b) irradiated steel samples of the RPV.

The activity of the steel samples was determined based on their ^{60}Co isotope. Following the radiochemical separation methods of the RNs, their activities and quantities will be determined based on LSC and ICP MS

3 Literature

[1] Yassin G., Barkleit A., Brendler, V., Microscopic characterization of un-irradiated and irradiated steel shielding material of a nuclear power plant, Institute of Resource Ecology HZDR, Annual Report 2020.
[2] Randelhardt U., Viehrig H. W., Koenheiser J., Schuhknecht J., Noack K., Gleisberg B. RPV material investigation of the former Greifswald VVER-440 NPP, Nuclear Engineering and Design 239(2009), 1581-1590.