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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Introduction

- Nuclear power plants NPPs: an important source of neutral CO_2 energy in Europe since a long time.[1]
- Fukushima accident in 2011: the German Bundestag issued a law to terminate the operation of the NPPs in Germany by the end of 2022.[2]
- Aim: Comprehensive plan that includes environmental assessment as well as radiological protection
- Reactor pressure vessel RPV of the Greifswald NPP: the main shielding barrier of the radioactive fuel to the outer environment. [3]
- Investigation of the microstructural features and the radioactive inventory of the RPV steel shielding material

a) Surface analysis methods based on scanning electron microscopy / energy dispersive X-ray spectroscopy SEM / EDX.
b) Gamma spectrometry measurements: most notably ^{60}Co, in nondestructive measurements in order to determine the activity of the irradiated samples.
c) Radiochemical separation method / Full combustion method followed by Liquid scintillation counting LSC measurements. The activity of the long lived beta emitting RNs are determined . In this context the RN ^{14}C ($t_{1/2}$= 5740 years) has been determined.

Experimental

a) Scanning electron microscopy / energy dispersive X ray spectroscopy SEM / EDX

- RPV Unit 8 :2nd generation of the Russian WWER-440 type.
- Normal Operation mode: not performed.
- Conditions: cut into specimens, neutron irradiated in JRC-Petten laboratories for a period of one year.
- Analysis: SEM / EDX measurements of both un-irradiated and irradiated samples

b) Radiochemical Analysis:

- RPV Unit 2: 1st generation WWER-440 of Greifswald NPP.
- Operation mode: shut down after 15 years operation .
- Conditions: Trepans were taken from the walls of the RPV at different sites and this is briefly described in table 1.
- Analysis: The activity of the steel samples has been determined, based on ^{60}Co, using high purity Germanium detector. The long lived ^{14}C concentration has been determined after full combustion method using a commercial oxidizer Hidex 600 ox., followed by LSC measurements.

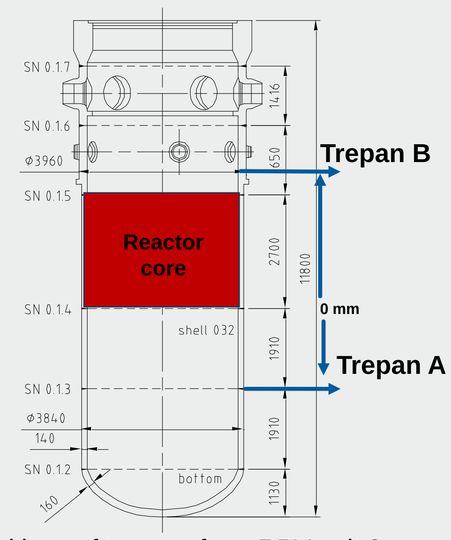

Table 1. Sampling positions of trepans from RPV unit 2.

Trepan	Position		
	Axial(mm)	Azimuthal(º)	Distance from inner wall (mm)
A	-1581	30	7.5,39,71,102.5
B	3000	30	7.5,39,71,102.5

Results

a) Scanning electron microscopy / energy X-ray dispersive spectroscopy SEM / EDX

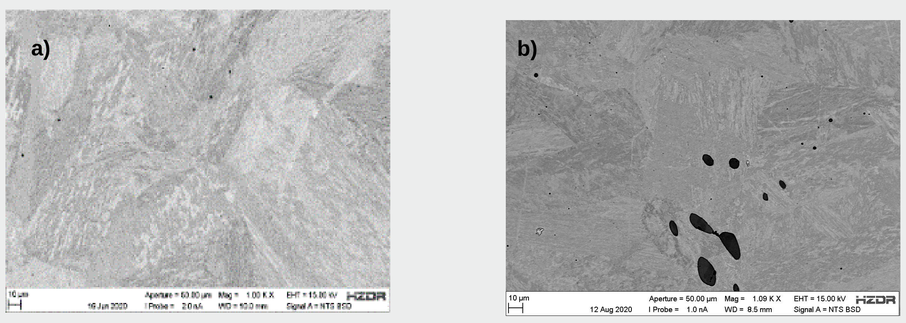

Fig. 1 SEM measurements of steel samples from the RPV unit 8, showing the microstructural features of (a) un-irradiated and (b) irradiated both at 10 µm resolution. The latter reveals the presence of high surface area of dark clusters containing MnS inclusions, and the distribution of white precipitates of Molybdenum.

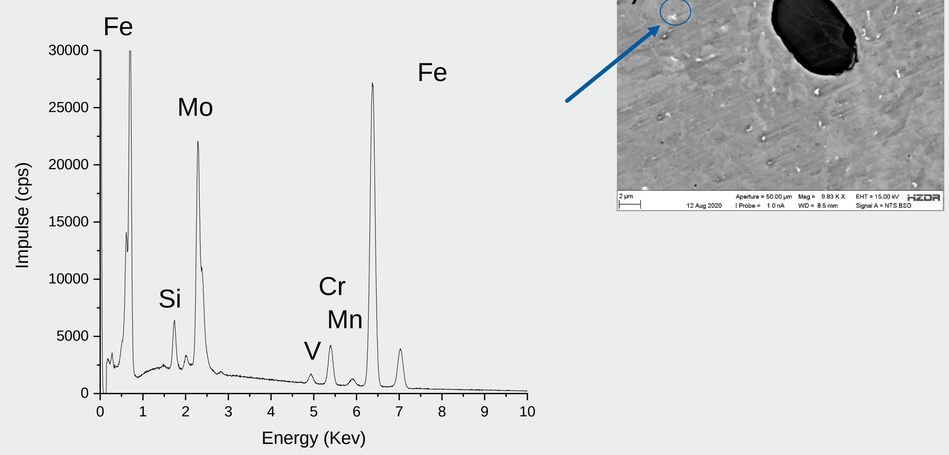

Fig. 2 Identification of the chemical composition present in the bainitic ferrite plates of the irradiated RPV steel shielding metal based on their energies (Kev) in the EDX experiments at accelerating voltage: 15kV.

b) Radiochemical analysis

The measured ^{60}Co concentration in the RPV steel samples revealed that the upper trepan (B) has a higher activity than the lower trepan (B). The activity at the upper part (A) varied in the range of 837 ±156 and 230 ± 10 Bq/g, where as at the lower part varied in the range of 8.29 ± 1.51 and 14.7 ± 11.28 Bq/g, respectively. The long lived ^{14}C measurements and their concentration distribution are shown figure 3.

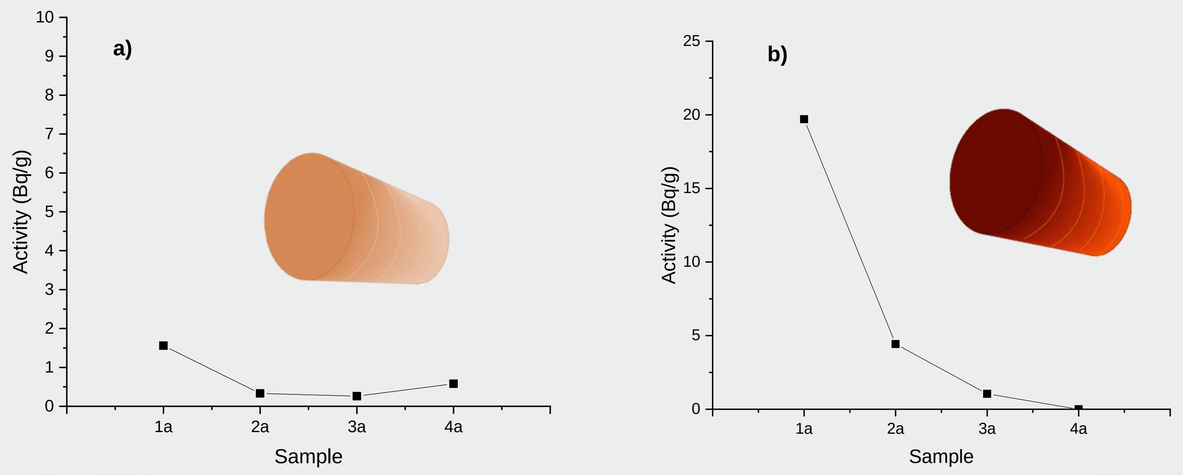

Fig. 3 ^{14}C concentration along the thickness of the steel shielding material a) the lower part: Trepan A and b) the upper part: Trepan B of the RPV Greifswald NPP decommissioned Unit 2.

Conclusions

The main goal of this study was to determine the impact of the long term irradiation on the steel shielding material of the RPV, and the activity distribution within its material after a long term operation. In this frame, the influence of the irradiation on the material composition has been investigated. Furthermore, the analysis of the gamma emitting RNs ^{60}Co has been measured, underlying the results of the activity distribution along the RPV of the decommissioned Unit 2 after long term operation. ^{14}C concentrations, that were produced and deposited within the RPV has been also determined.

Acknowledgements

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References

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