Soil Activation Studies for the FAIR Project

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For the planning of the shielding of the new FAIR accelerator facilities, as well as for the governmental approval procedures, we need to study the amount of radioactivity induced by the operation of the new accelerators in the soil surrounding the beam tunnels and especially in the groundwater. The latter is particularly important because radiation exposure to the general population can be caused by radioactive nuclei that are produced in the soil, then migrate to groundwater and subsequently are transported to inhabited areas.

Method

As a first step, soil activation experiments have been performed in order to get a rough estimate of the nuclides that will be produced in soil (see [1]). These experiments also served as a test for the accuracy of the Monte-Carlo code FLUKA [2] that is used for the estimation of the activity produced around the SIS100/300. Comparison between calculations and the measurements showed in general quite good agreement. In a second step the induced radioactivity around the beam tunnel of the planned SIS 100/300 accelerator ring was calculated.

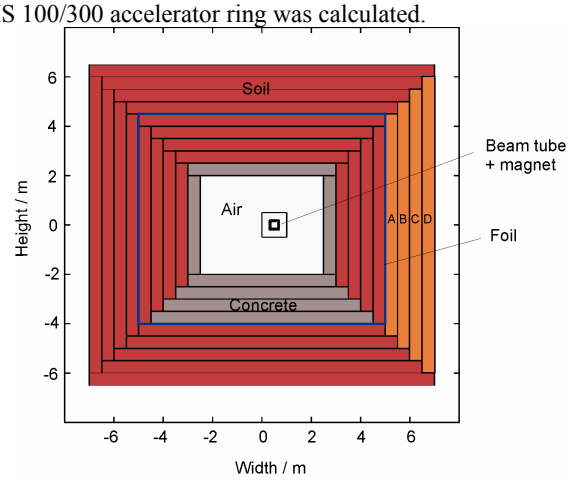

Figure 1: Input geometry for the FLUKA calculations

The input geometry used for the FLUKA calculations (see Fig. 1) is a straight rectangular tube. The walls and the surrounding soil were composed from layers with thicknesses of 50 cm. In order to prevent the radioactive nuclei produced around the tunnel walls from migrating to the groundwater, it was planned to insert a foil into the soil in a distance of 2 m around the tunnel walls, so that only the activation in the soil layers outside of the foil needed to be considered. For this calculation we assumed that all beam losses occur at the right side in Fig. 4. In the following we only considered the 4 layers marked with A, B, C and D because in this scenario they will have the highest activity concentrations. The calculations were performed for a ^{238}U beam with E=2.7 GeV/u, an intensity of 10^{12} / s and a total beam loss of 10% per second.

Results

In order to estimate the radiation exposure resulting from soil activation and subsequent ground water migration, several other aspects were investigated in addition to the actual activation, specifically the migration to groundwater (see Ref. 3), decay during transportation, and dilution within the groundwater.

Nuclide	**Half-live**	**irradiation- / decay-time**		
		10 a / 100 d	**10 a / 10 a**	**50 a / 10 a**
H-3	12.3 a	0.0174	0.0101	0.0221
Be-7	53.3 d	0.00565		
C-14	5730 a	$5.80 \cdot 10^{-4}$	$2.45 \cdot 10^{-4}$	$1.22 \cdot 10^{-3}$
Na-22	2.6 a	0.0560	0.00419	0.00450
Mn-54	312.2 d	$1.44 \cdot 10^{-3}$		
Fe-55	2.73 a	$5.25 \cdot 10^{-5}$	$4.42 \cdot 10^{-6}$	$4.82 \cdot 10^{-6}$
Co-60	5.27 a	$5.03 \cdot 10^{-5}$	$1.40 \cdot 10^{-5}$	$1.92 \cdot 10^{-5}$
Cs-134	2.06 a	$1.78 \cdot 10^{-5}$		
Eu-152	13.3 a	$6.49 \cdot 10^{-5}$	$3.94 \cdot 10^{-5}$	$9.07 \cdot 10^{-5}$
Sum		**0.0822**	**0.0146**	**0.0279**

Table 1: Specific activities in groundwater in units of the legal limits (StrlSchV Appendix VII, Table 4)

The resulting normalized activity concentrations of the most relevant nuclides are given in Table 2 for three different combinations of irradiation and decay times. For an estimate of the maximum real activity concentration, the last column with 50 years irradiation time and 10 years decay seems to be the most realistic scenario since the transportation time out of the FAIR facility will be about 5-15 years, and the total operating life of FAIR will be at the order of several decades. The last row of Table 2 gives the sum of the normalized activity concentrations for all nuclides. The value is far below 1 which means that the activity stays well below the legal limits.

References

[1] K. Vogt, M. Haida, and G. Fehrenbacher, GSI Scientific Report 2007, p. 249
[2] FLUKA: http://www.fluka.org
[3] X. Lin, Ch. Lierse von Gostomski, "Untersuchungen zur Freisetzung von Radionukliden aus Bodenproben in das Grundwasser", Lehrstuhl für Radiochemie, TU München.