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Nuclide inventory in proton irradiated lead – comparison of simulation and measurement

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The ring cyclotron at the Paul Scherrer Institute's (PSI) accelerator facility produces at present protons of 590 MeV with a current of up to 2.3 mA. After penetrating two graphite targets with an effective thickness of 0.5 cm and 4 cm, the beam is dumped into the target of the neutron spallation source SINQ. This target consists of several rows of steel tubes (nowadays Zircaloy) filled with lead. After 2 years in operation, the target has become highly activated and needs to be replaced due to the fatigue of the material. After a cooling period, the target will have to be disposed as radioactive waste. For this procedure the nuclide inventory is required by the authorities. For components directly activated by the proton beam, it is calculated using MCNPX coupled to build-up and decay codes like SP-FISPACT07 and Cinder'90.

The calculated nuclide inventory is compared to measured activities of several isotopes extracted from a central lead rod of SINQ target 4, which was irradiated with 10 Ah. The rod was cut into several pieces. Two pieces from different positions along the lead rod were analyzed employing radiochemical preparation where necessary. The gamma-measurements were made with a high-purity germanium detector (HPGe). The beta-activities were determined with Liquid Scintillation Counting (LSC). For long-lived radionuclides such as Al26 and Cl36, Accelerator Mass Spectrometry (AMS) was used. Due to the position of the two samples, they have seen different compositions of proton and neutron flux spectra, which leads to a different nuclide inventory. Since the sizes of the samples are quite small, more effort was needed to achieve a reasonable statistical error in the Monte Carlo simulation.

In addition, the dose rates around the target were measured during the remote-controlled dismantling in the hotcell. They were compared to the predictions made with MCNPX and Cinder'90.

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