Source term analysis for MYRRHA

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Abstract

MYRRHA (Multi-purpose hYbrid research Reactor for high-tech Application) is a prototype of a nuclear reactor driven by a LINAC particle accelerator working at a reasonable level of power and current (100 – 600 MeV and 2.4 – 4 mA). Moreover, it is a flexible facility which is able to work in both subcritical (65-75 MWth) and critical mode (100 MWth).

After maintenance and/or after operating life, wastes coming from MYRRHA will need to be disposed or treated properly. A list of possible waste was calculated with ALEPH2.5 depletion code.

From the accelerator, waste will mainly come from the concrete surrounding the accelerator. This concrete will be activated by neutrons and a tiny bit by protons. At the end of the accelerator, a beam dump, designed to absorb the proton beam delivered by the accelerator, will also be activated by protons and neutrons. The design for the beam dump is still under investigation but it could be composed of beryllium and aluminium, leading to the presence of mainly Be-7, Li-8, He-6, B-8, Mg-27, Al-28, Al-26m at short-term and mainly Al-26 and Be-10 at longer-term.

The coolant and the spallation target generating neutrons driving the core is composed of Lead-Bismuth Eutectic (LBE). Most of the radioactive nuclides present in the LBE will be produced by spallation (from high-energy proton interactions with LBE), by fission (from fission neutrons) and by neutron capture reactions (from slower neutrons). Problematic nuclides coming from the activation of the LBE will mainly be H-3; N-16; O-19; isotopes of Krypton, Xenon, Mercury and Po-210 as well as nuclides belonging to the production chains of Bi-207, Bi-210, Pb-209 and At-210.

The nuclear core is mainly composed of the fuel pins (MOX fuel), the fuel cladding (austenitic steel 15-15Ti), the core barrel and the vessel (austenitic AISI 316L steel), the beam tube and window (martensitic steel T91), and the cover gas. From the fuel pins, the activity should be mainly determined by Np-239 and U-239 at short term, and Pu isotopes, Am-241, Th-230 and daughter nuclides at longer term. From the fuel cladding, the major contributors into the short-term activity are Mn-54,56, Fe-55 and Co-58, while Co-60, Ni-63, Ni-59, Tc-99, Mo-93 and Nb-93m are the major contributor into the long-term activity. From the core barrel and the reactor vessel, Mn-56 gives the highest activity just after shut-down while Co-60, Cr-51, Ni-59 and Ni-63 will determine the activity at longer-term. The beam tube and window will be activated by both protons and neutrons. The short-term activity is determined mainly by Mn-56, Cr-51 and Mo-99 for the beam tube while V-48 is also present for the window. At longer term, Fe-55, Ni-63, Nb-93m,94 and Tc-99m determine the activity for the beam tube, while H-3, Ar-39, Ti-44, Sc-44, Cl-36 are also present for the window. Finally, volatile and gaseous products of LBE irradiation will migrate to the cover gas. At very short-term, Po-210 and isotopes of Mercury show the highest activity. At longer-term, Hg-194 and its daughter Au-194, and finally Kr-81 will dominate the activity.