Comprehensive modeling of activated water radiation sources of ITER Tokamak Cooling Water System

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The activated water has been identified as a relevant radiation source in fusion facilities during plasma operation. In ITER, cooling water is activated near first-wall components due to the intense neutron exposure and carries the produced radioisotopes far from the irradiation region. This phenomenon generates complex radiation fields outside the bioshield, directly impacting on the design of radiation shielding, radiological zoning, and licensing of the facility in regions where plasma neutrons are negligible. Hence, the accurate characterization of the activated water radiation source and its impact on the entire facility is critical for the project.

The Tokamak Cooling Water System (TCWS) is itself an enormous and highly complex network comprising multiple circuits organized in closed loops with varying extension and neutron exposure levels depending on the component of the tokamak that they cool. This results in a highly heterogeneous thermohydraulic network where radionuclides concentrations vary in several orders of magnitude. The characterization of the radionuclide production, decay and transport, and the associated dose fields is, therefore, a problem coupling neutronics and thermohydraulics.

In previous assessments of the TCWS activated water radiation source, pure water was assumed as coolant, resulting in the production of dominant but short-lived nuclides such as ^{16}N and ^{17}N. However, the implementation of realistic water chemistry to control the pH and minimize corrosion products introduces new activation pathways leading to the production of longer-lived radionuclides. The decay of these radioisotopes becomes relevant after a few minutes of transient time. Consequently, several TCWS sub-circuits that were previously disregarded because of the rapid decay of short-lived nuclides must now be reassessed.

To address these challenges, the TCWS has been modeled from scratch according to the latest designs. All principal and auxiliary cooling loops containing water during plasma operation have been considered. Updated thermo-hydraulic parameters to accurately describe flow rates and residence times have been used to compute the radionuclide activities in each pipe segment. The resulting geometry, composed of approximately 35,000 individual solids including pipes, water cells, filters and tanks, has been fully integrated into the ITER MCNP Full Model describing the entire facility. This integration enables a realistic evaluation of radiation transport from activated water sources within the global ITER radiation environment. A comprehensive nuclide inventory has been considered. Gamma and neutron emitting radiation sources have been generated for each circuit and isotope independently using the FLUNED-SL toolkit, and subsequently analyzed with D1SUNED to obtain the corresponding dose distributions.

The outcome of this work is a comprehensive, fully circuit-resolved, time-dependent and chemistry-consistent radiation source of ITER activated water during plasma operation. The results provide important input for the new release of ITER radiation maps supporting the forthcoming update of the ITER Safety Report.

Type of contribution:	Poster session	☐
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