Radiological Safety Assessment of a Spent Fuel Storage Facility

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Abstract

A modern facility for storing irradiated Pressurised Heavy Water Reactor fuel has recently been commissioned in India. The fuel bundles are placed in a rack of 20 trays, with 11 bundles per tray. The facility has several advanced safety features like stainless steel liner for the pool cavity, provision to monitor leakage from pool liner, prevention of over-ground flooding, and monitoring of ground water infiltration. The building ventilation air is exhausted through grills situated above the pool water level and released through a 20m stack, after full filtration.

The pool building, the pool water cooling and purification system, and the ventilation system are all designed for Operating Basis Earthquake (OBE) condition. However, the fuel tray and the stack are not designed for OBE conditions, leading to the possibility of fuel bundles falling to the bottom the SFSF pool, the pins coming loose and possibly failing by mechanical damage. The Indian experience regarding fuel damage during such conditions is limited, but in all such incidents the pins retained their clad integrity. A radiological safety analysis was, therefore, required to conservatively assess the scope of damage and the resultant consequences, and to develop an emergency response plan for the plant.

For safety assessment, a failed fuel bundle was defined as one that had at least one pin failed. To quantify the radioactive release following an OBE, a parametric study was made on the number of bundles failed, the number varying from 1% to 100% of stored bundles. The work involved estimation of on-site gamma exposure to assess habitability in the Control Room of the facility, and access to the polishing unit. In addition to calculations using point kernel method, a Monte Carlo simulation was carried out to map the radiation levels at various key locations in and around the facility. The analysis also quantified the off-site radiological dose using a Gaussian Plume Model.

The analysis shows that the gap inventory of a 3-y cooled bundle contains significant activity of ^{85}Kr, ^{134}Cs, and ^{137}Cs only. The off-site dose depends on site meteorology, while the on-site dose depends on factors like scatter dose, pool decontamination rate, and efficiency of the pool air curtain. The public dose at the site boundary is calculated to be low (1.41 µSv for 100% bundle failure). The on-site dose comprises i) submersion dose from ^{85}Kr if it escapes the air curtain, and ii) gamma-shine from the water surface due to the released cesium activity. The former gives, with 1% of stored bundles failed, a submersion dose rate of 0.11 mSv/h for air-curtain efficiency of 90%, and dose rates of 13 mGy/h at the pool railings and <0.15 mSv/h in the control room.

An emergency recovery plan for the plant was based on the failed bundles not exceeding 5%. It involves installing mobile shields in the ion exchange area and using a truck-mounted ion-exchange decontamination unit. A long-term stabilisation plan for caging tray stacks has already been set in motion.

KEYWORDS: OBE, gap inventory, off-site dose, on-site dose

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