**Simulation-Based Assessment and Validation of Radiological Environmental Impacts from the Oceanic Discharge of ALPS Treated Water**

**Daisuke Tsumune,1,2,\* Kazuhiro Misumi,2 Takaki Tsubono,2**

**Tomomi Okamura,3 Hiroshi Abe,3 Hiroaki Kato,1 and Yuichi Onda,1**

*1University of Tsukuba, 305-8572 Tsukuba, Japan*

*2Central Research Institute of Electric Power Industry, 270-1194 Abiko, Japan*

*2* *Fukushima D&D Engineering Company, Tokyo Electric Power Company Holdings, Inc., Japan*

\* *e-mail: tsumune.daisuke.gw@u.tsukuba.ac.jp*

The water treated by the Advanced Liquid Processing System (ALPS treated water) has been released into the ocean since August 2023, as part of the decommissioning process of the Fukushima Daiichi Nuclear Power Station (1F) by Tokyo Electric Power Company Holdings, Inc. (TEPCO HD). Radioactive nuclides, including tritium (³H), are routinely discharged into the ocean from nuclear facilities worldwide. However, ocean discharge from an accident-affected nuclear power plant is unprecedented. Moreover, concerns were raised domestically and internationally, as long-lived radionuclides such as carbon-14 (¹⁴C) and iodine-129 (¹²⁹I) cannot be completely removed. Therefore, TEPCO HD prepared a "Radiological Environmental Impact Assessment Report," which was reviewed and deemed appropriate by the International Atomic Energy Agency (IAEA). In the report, a Regional Ocean Modeling System (ROMS) was applied to the coastal waters off Fukushima to evaluate the dispersion of ALPS-treated water. The model incorporated results from the Japan Meteorological Agency’s short-term weather forecasting system and ocean reanalysis data (JCOPE2M), considering the effects of wind stress, the Kuroshio Current, and mesoscale eddies. The model’s reproducibility was validated through the simulation of cesium-137 (¹³⁷Cs) dispersion following the Fukushima accident, showing good agreement with observed annual average concentrations. It was also demonstrated that the annual variability in average concentration distributions was small, suggesting that future annual average concentrations could be predicted if discharge rates are known. The discharge rate for ALPS-treated water was set to ensure that annual tritium releases would not exceed 22 TBq. Discharge rates for 29 other nuclides were also determined based on the composition of the treated water. Model simulations indicated that areas where tritium concentrations exceed the pre-accident background level (70 Bq/m³) would be limited to offshore Fukushima. Based on IAEA and International Commission on Radiological Protection (ICRP) guidelines, average marine concentrations of 30 major nuclides were estimated proportionally, and both external and internal exposure doses were evaluated. The results showed that the additional dose would be on the order of 10⁻⁵ mSv/year, which is negligible compared to natural background radiation levels (1–2 mSv/year). Although the dose was extremely low, carbon-14 and iodine-129 contributed relatively more than tritium. From August 2023 to August 2024, approximately 4.5 TBq of tritium was discharged, equivalent to about one-fifth of the annual limit. Validation of the evaluation model using monitoring data is essential. Although monitoring of tritium concentrations in the surrounding marine area has been conducted, large temporal and spatial variations have made it difficult to capture detailed concentration distributions. Furthermore, the locations of maximum concentrations have not always been precisely monitored. Minor residual leakage from the 1F site and its vicinity has contributed to background concentrations remaining higher than pre-accident levels, although the impacts have been localized and limited. Nevertheless, detectable impacts on background concentrations have been limited to the vicinity of the discharge outlet, which is consistent with model predictions. These findings are critical for verifying the safety of the discharge. Going forward, it will be important to continue ensuring safety by accumulating monitoring data, conducting detailed verification of the model, and updating the simulation as necessary to reflect new observations.