IAEA Review of Safety Related Aspects of Handling ALPS Treated Water at TEPCO's Fukushima Daiichi Nuclear Power Station

Independent Sampling and Analysis for the Determination of Radionuclides in Samples of ALPS Treated Water from Tank Group K4-A

Introduction

Analyses of samples from tank group K4-A, the contents of which comprise the third batch of ALPS treated water planned to be discharged from Fukushima Daiichi Nuclear Power Station (FDNPS) have been undertaken within the framework of the IAEA's ongoing activities to corroborate measurements of radionuclides in samples taken from FDNPS and the surrounding environment [1, 2]. These corroboration activities provide an independent check of the veracity of the radiological data resulting from source and environmental monitoring programmes related to the ALPS discharges upon which the safety related aspects of the discharges of ALPS treated water are being evaluated. The specific corroboration activity reported here has been designed to verify the results of TEPCO's analyses for the activity concentration of ^{3}H (tritium) in the third batch of ALPS treated water to prior to discharge.

Samples were taken, after homogenisation of the water content of the tanks using the standard infrastructure installed at FDNPS for this purpose [1], in July 2023. The samples were analysed by TEPCO and in the IAEA laboratories in Austria and Monaco. The results of the analyses for ^{3}H activity concentrations were compiled by the IAEA and statistically evaluated by calculating a zeta (ζ) score [3] to assess comparability. ^{3}H was selected as the primary focus of the analysis as it is the only radionuclide that should exceed Japanese regulatory limits prior to dilution and discharge.

The samples were also screened for alpha, beta and gamma emitting radionuclides in the IAEA laboratories to verify that other radionuclides were not present in significant quantities. For the purposes of this screening, the IAEA used relevant Japanese regulatory limits to define what is considered significant.

Results and Conclusions

The results of the analyses for ^{3}H and the ζ score are presented in Table 1.

Table 1. ^{3}H Activity concentrations, combined standard uncertainties, detection limits (in parentheses) (Bq/L) and ζ score for K4-A ALPS treated water.

Activity concentration/ detection limit (Bq/L)		Zeta (ζ) score
IAEA	TEPCO	
128350 ± 870 (830)	126600 ± 4100 (20)	-0.42

A ζ score between -2 and 2 indicates that the reported result is accepted at a 95.4% confidence level. In this case the ζ score was -0.42 and, thus, it can be concluded that the results for ^{3}H activity concentration in the samples from K4-A reported by TEPCO agree with a high level of confidence with the IAEA results.

The results of screening analyses for alpha and beta-emitting radionuclides indicate that levels of these radionuclides were lower than the most restrictive applicable regulatory limits: 4 Bq/L for ^{238}Pu, ^{239}Pu and ^{240}Pu (alpha emitters), and 9 Bq/L for ^{129}I (beta emitter[1]). Therefore, based on the results of the analytical methods used, it can be inferred that alpha and beta emitting radionuclides present in the samples are at levels that are significantly below relevant Japanese regulatory limits.

Screening for gamma-emitting radionuclides was undertaken by analysing the samples using gamma-ray spectrometry. Activity concentrations of the gamma-emitting radionuclides ^{60}Co, ^{129}I and ^{137}Cs were detected, however the measured values were much lower than the respective regulatory limits in all cases. All other gamma-emitting radionuclides were below respective detection limits which were also much lower than the respective regulatory limits in all cases.

Therefore, based on its analysis, the IAEA has concluded that:

- The results for ^{3}H (tritium) activity concentration from TEPCO's analysis and from the IAEA's analysis agree with a high level of confidence.
- Based on the results of the analytical methods used, the IAEA did not detect any other radionuclides in significant quantities (relative to relevant Japanese regulatory limits).

[1] Radioactive decay of ^{129}I results in the emission of both beta and gamma radiation and thus can be screened using both gross beta and gamma-ray spectrometry.

Detailed Information

Design and Participating Laboratories

Analyses were undertaken by TEPCO and by the following IAEA Nuclear Sciences and Applications Laboratories:

- IAEA Marine Environment Laboratories, Radiometrics Laboratory (RML), Monaco; and
- Terrestrial Environmental Radiochemistry Laboratory (TERC), Seibersdorf, Austria.

Collection and Preparation of the ALPS Treated Water Sample

Samples for this analysis were collected on 10 July 2023 from the K4-A storage tanks at FDNPS, with IAEA staff present. The contents of the tanks had been homogenised using the standard infrastructure installed at FDNPS for this purpose [1]. ALPS treated water was sampled directly from one of the interconnection pipes at K4-A. The IAEA Laboratories' sample containers were assigned and labelled beforehand and were immediately sealed with tamper proof tape under IAEA observation. The samples were not acidified or filtered prior to shipping to the IAEA Laboratories.

Analytical Methods

^{3}H Analysis.

The IAEA laboratories employed direct counting by Liquid Scintillation Counting (LSC) whereby an aliquot of sample was added directly into a Teflon-coated LSC vial and mixed it with a scintillation cocktail. It was stored in a dark location for approximately 12 hours prior to measurement. Recovery was based on a metrologically traceable standard solution, using the same region of interest as the samples [4].

TEPCO prepared the sample by removing organic matter and interfering radionuclides via distillation [4,5], followed by LSC.

Gross Alpha and Gross Beta Analysis

For screening alpha and beta emitting radionuclides, the IAEA used co-precipitation methods followed by LSC [6,7]. These methods were previously determined to be appropriate for the analysis of ALPS treated water samples [8]. Contributions from ^{3}H to the gross beta activity were excluded. The IAEA acknowledges that the use of these co-precipitation methods may exclude contributions to the gross beta activity from some beta-emitting radionuclides, notably ^{14}C.

Gamma-emitting Radionuclide Analysis

Samples were analysed for the gamma-ray emitting radionuclides ^{54}Mn, ^{60}Co, ^{106}Ru, ^{125}Sb, ^{129}I, ^{134}Cs, ^{137}Cs, ^{144}Ce, ^{154}Eu, ^{155}Eu and ^{241}Am included in TEPCO's ALPS treated water source

term by gamma-ray spectrometry using high purity germanium (HPGe) detectors by both the IAEA laboratories. ^{106}Ru was determined by gamma-ray spectrometry via decay of its progeny ^{106}Rh.

Presentation of results

In this report, each measurement result is stated in the format x $\pm$ y, where x is the activity concentration and y is the numerical value of the combined standard uncertainty, i.e. with a coverage factor of $k = 1$.

Reported activity concentrations are stated with a number of decimal places based on the first two significant figures of the associated uncertainty. Detection limits are also reported to two significant places. Both uncertainties and detection limits are rounded up. Activity concentrations are rounded up or down according to normal rules for rounding [9].

Statistical Evaluation of the Results

The ^{3}H activity concentration measured by TEPCO was reported to the IAEA and statistical evaluated against a single, consistency checked result from the IAEA Laboratories. The method used for the comparison was a ζ (zeta) score [3], calculated as follows:

$$\zeta = \frac{x_{TEPCO} - x_{IAEA}}{\sqrt{u^2(x_{TEPCO}) + u^2(x_{IAEA})}}$$

where TEPCO's and the IAEA Laboratories' results – activity concentration and standard ($k = 1$) uncertainty – are $x_{TEPCO} \pm u(x_{TEPCO})$ and $x_{IAEA} \pm u(x_{IAEA})$.

Following the current ISO standard for statistical methods for used in proficiency testing [3], this ζ score is interpreted as follows:

- A ζ score between -2 and 2 indicates that the reported result is accepted at a 95.4% confidence level;
- A ζ score between 2 and 3 or between -2 and -3 is considered to give a "warning signal"; and
- A ζ score greater than 3 or less than -3 indicates that the reported result is not accepted at a 99.7% confidence level, and gives an "action signal".

References

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA Comprehensive Report on the Safety Review Of The ALPS-Treated Water at the Fukushima Daiichi Nuclear Power Station https://www.iaea.org/sites/default/files/iaea_comprehensive_alps_report.pdf.

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA Review of Safety Related Aspects of Handling ALPS-Treated Water at TEPCO's Fukushima Daiichi Nuclear Power Station, First Interlaboratory Comparison on the Determination of Radionuclides in ALPS Treated Water https://www.iaea.org/sites/default/files/first_interlaboratory_comparison_on_the_determination_of_radionuclides_in_alps_treated_water.pdf.

[3] INTERNATIONAL ORGANISATION FOR STANDARDISATION, Statistical methods for use in proficiency testing by interlaboratory comparisons, ISO 13528:2022, Geneva (2022).

[4] INTERNATIONAL ORGANISATION FOR STANDARDISATION, Water quality–- Tritium–- Test method using liquid scintillation counting. ISO 9698:2019, Geneva (2019).

[5] Ministry of Education, Culture, Sports, Science and Technology Radioactivity Measurement Series 9 Radioactive Tritium Analysis Method.

[6] INTERNATIONAL ORGANISATION FOR STANDARDISATION, Water Quality – Gross alpha and gross beta activity – Test method using liquid scintillation counting. ISO 11704:2018, Geneva (2018)

[7] KLEINSCHMIDT, R, Gross alpha and beta activity analysis in water – a routine laboratory method using liquid scintillation analysis. (2004).

[8] INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA Review of Safety Related Aspects of Handling ALPS-Treated Water at TEPCO's Fukushima Daiichi Nuclear Power Station, Report 3: Status of IAEA's Independent Sampling, Data Corroboration, and Analysis https://www.iaea.org/sites/default/files/3rd_alps_report.pdf.

[9] BELL, S., Good Practice Guide No. 11, The Beginner's Guide to Uncertainty of Measurement. https://www.npl.co.uk/special-pages/guides/gpg11_uncertainty.