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

Additional Measures for Independent Sampling and Analysis Related to Discharges of ALPS Treated Water

– Additional Measures February 2025: Source Monitoring

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1. INTRODUCTION

The main objective of Additional Measures for Independent Sampling and Analysis Related to Discharges of ALPS (Advanced Liquid Processing System) Treated Water (hereafter referred to as "Additional Measures") is to further increase transparency by facilitating the wider participation of stakeholder countries, through the IAEA's Analytical Laboratories for the Measurement of Environmental Radioactivity (ALMERA[1]) network [1] member laboratories, in independent sampling and analysis related to discharges of ALPS treated water under the framework of the IAEA.

The IAEA and Japan concurred in September 2024, to implement the Additional Measures under the framework of the IAEA. The Agency confirms that this agreement builds upon its existing sampling and monitoring activities in compliance with the IAEA statutory functions.

Therefore, the Additional Measures outlined herein are intended to be a key component of the ongoing IAEA programme and will be executed under the authority of the IAEA. The scope of the Additional Measures encompasses the following activities:

a) **Source Monitoring (Post-ALPS Treatment, Pre-Dilution)**: This involves independent sampling and analysis of ALPS treated water sourced from the measurement and confirmation facility, specifically the tanks where the water is stored, homogenized, and tested prior to release.

b) **Monitoring at Discharge Vertical Shaft/Seawater Pipe Header (Post-Dilution)**: This comprises independent sampling and analysis of the diluted ALPS treated water.

c) **Marine Environmental Monitoring (Post-Discharge)**: This includes independent sampling and analysis of seawater and fishery products.

In February 2025, the IAEA carried out this Additional Measures mission through sampling of ALPS treated water in the source water tanks at TEPCO's Fukushima Daiichi Nuclear Power Station (FDNPS). This report presents the results of subsequent analyses for radionuclide activity concentrations conducted by TEPCO, by the IAEA laboratories in Monaco and Japan, and by member laboratories of the ALMERA Network from China, France, the Republic of Korea, and Switzerland. Additionally, it includes the results of an intercomparison of these measurement results which was carried out by the IAEA according to international best practice for proficiency testing [2].

[1] ALMERA is a network currently comprising more than 200 member laboratories globally. It provides a platform for maintaining and developing capability on the determination of radionuclides in air, water, soil, sediment and vegetation that can be used for both routine and environmental emergency monitoring in the IAEA Member States.

2. PARTICIPATING LABORATORIES

The participating laboratories are presented in Table 1.

TABLE 1. PARTICIPATING LABORATORIES

Identifier	Participant
IAEA	IAEA Marine Environment Laboratories, Monaco and IAEA Fukushima ALPS Laboratory, Japan
ASNR	French Authority for Nuclear Safety and Radiation Protection (L'Autorité de sûreté nucléaire et de radioprotection)
CIRP	China Institute for Radiation Protection, China
KINS	Korea Institute of Nuclear Safety, Republic of Korea
SPIEZ	Spiez Laboratory (Labor Spiez), Switzerland
TEPCO	Tokyo Electric Power Company Holdings, Inc., Japan

The IAEA gratefully acknowledges the support of the Laboratorio de Medidas de Baja Actividad de la Universidad del Pais Vasco UPV/EHU, accreditation number 350/LE560 under Entidad Nacional de Accreditacion, in conducting confirmatory analyses for ^{14}C and ^{99}Tc on its behalf.

3. SAMPLE COLLECTION AND PRETREATMENT

Samples of ALPS treated water were taken on 21 February 2025 from the K4-A tank group, part of the measurement and confirmation facility at FDNPS. The water contained in the K4-A tank group was being prepared to be the 12th batch of ALPS treated water to be discharged, subject to a compliance with authorized limits as demonstrated by source monitoring. To ensure homogenization and representative sampling of the entire batch, the water had been circulated between interconnected tanks in the K4-A tank group and agitated within individual tanks for more than 144 hours prior to sample collection, following TEPCO's standard pre-sampling protocol for source monitoring.

The samples were collected directly from a valve in one of interconnection pipes at K4-A. Each participating laboratory was provided with a sample comprised of 10 L of ALPS treated water: 2 x 5 L in plastic jerrycan containers. The IAEA staff members and experts from the ALMERA member laboratories took the opportunity to fill the container that would subsequently be shipped to their laboratories for analysis. The samples were not acidified or filtered prior to shipping.

The sample containers were assigned and labelled beforehand and were immediately sealed with tamper proof tape. A unique sample ID and recipient laboratory were recorded to facilitate the traceability of each sample container. The samples were then checked, boxed and shipped to all participating laboratories for analysis.

4. ANALYSES

Participating laboratories were requested to analyse the samples of ALPS treated water for activity concentrations of ^{3}H, ^{14}C, ^{60}Co, ^{90}Sr, ^{99}Tc, ^{106}Ru, ^{125}Sb, ^{129}I, ^{134}Cs and ^{137}Cs using an appropriate analytical method.

Reporting forms and target detection limits were provided by the IAEA. Participating laboratories were requested to submit a single measurement result for each sample and radionuclide analysed, comprised of an activity concentration, standard combined uncertainty (k=1) and detection limit. They were asked to report activity concentrations for a reference time of 21 February 2025 12:00 UTC.

5. STATISTICAL EVALUATION OF THE RESULTS

The IAEA compiled and evaluated the results submitted by all participating laboratories. The method used for the statistical evaluation depended on the number of results received for each radionuclide.

If four or more measurement results above the detection limit were received, a comparison reference value x_{ref} was determined as a power-moderated mean of the combined results [3]:

$$x_{ref} = \sum_{i=1}^{N} w_i x_i$$

where x_i is the value reported by the laboratory i, N is the number of results reported and w_i is a normalized weighting factor.

A ζ (zeta) score was then calculated for each laboratory as follows.

$$\zeta = \frac{d_i}{u(d_i)}$$

where $d_i = x_i - x_{ref}$, the difference between the value reported by the laboratory x_i and the reference value x_{ref}, and $u(d_i)$ is the standard uncertainty associated with d_i, taking the correlation between individual results and the reference value into account.

Following the current ISO standard for statistical methods for use in proficiency testing [4], for zeta scores between -3 and 3, the corresponding result was evaluated as agreeing with the reference value at a 99.7% confidence level and for zeta scores greater than 3 or less than -3 the reported result was evaluated as not agreeing at a 99.7% confidence level.

If two or three measurement results above the detection limit were received, then one or three direct zeta scores [4] were calculated. In this case, the zeta $\zeta_{i,j}$ score is defined as:

$$\zeta_{i,j} = \frac{x_i - x_j}{\sqrt{u_i^2 + u_j^2}} \qquad (1)$$

where:

- x_i is the value of laboratory i (Bq $unit^{-1}$);
- x_j is the value of laboratory j (Bq $unit^{-1}$);
- u_i is the standard uncertainty for the value of laboratory i (Bq $unit^{-1}$);
- u_j is the standard uncertainty for the value of laboratory j (Bq $unit^{-1}$); and
- $unit$ is the unit of volume or mass, L or kg, as appropriate for the particular sample type.

If two results were received, $\zeta_{1,2}$ was calculated, while for three received results $\zeta_{1,2}$, $\zeta_{1,3}$ and $\zeta_{2,3}$ were calculated. These zeta scores were evaluated using the same methodology described above for comparing measurement results against consensus reference values and their associated standard uncertainties.

6. RESULTS

The results submitted by the participating laboratories and associated consensus reference values are presented in Table 2 and Figures 1 – 8. The uncertainties quoted are combined standard uncertainties, i.e. with a coverage factor of $k = 1$. Table 3 contains the zeta scores.

TABLE 2. ACTIVITY CONCENTRATIONS (BQ L^{-1}) IN SAMPLES OF ALPS TREATED WATER

Nuclide	IAEA	ASNR	CIRP	KINS	SPIEZ	TEPCO	Reference
^{3}H	343400 ± 7500	391000 ± 17000	366500 ± 9800	374000 ± 7000	397100 ± 5100	368000 ± 11000	372900 ± 8100
^{14}C	14.1 ± 1.5	14.46 ± 0.53	12.7 ± 1.5	12.8 ± 1.7	-	12.3 ± 1.0	13.57 ± 0.48
^{60}Co	0.243 ± 0.014	0.25 ± 0.05	0.221 ± 0.030	0.243 ± 0.027	0.23 ± 0.01	0.231 ± 0.024	0.2348 ± 0.0074
^{90}Sr	0.635 ± 0.059	0.79 ± 0.06	0.772 ± 0.075	0.745 ± 0.064	0.70 ± 0.04	0.706 ± 0.036	0.717 ± 0.022
^{99}Tc	0.119 ± 0.013	<0.094	<0.21	0.234 ± 0.025	0.077 ± 0.007	0.187 ± 0.014	0.153 ± 0.035
^{106}Ru	<0.21	<1.8	<0.34	<1.2	<0.083	<0.22	-
^{125}Sb	0.117 ± 0.017	<0.52	0.114 ± 0.050	<0.41	0.10 ± 0.01	0.102 ± 0.030	0.1059 ± 0.0087
^{129}I	<1.1	<0.32	<1.4	0.116 ± 0.036	0.13 ± 0.03	0.1043 ± 0.0046	-
^{134}Cs	<0.021	<0.16	<0.036	<0.13	<0.006	<0.030	-
^{137}Cs	0.406 ± 0.021	0.42 ± 0.06	0.406 ± 0.030	0.396 ± 0.028	0.39 ± 0.02	0.403 ± 0.037	0.401 ± 0.012

TABLE 3. ZETA SCORES FOR ACTIVITY CONCENTRATION OF RADIONUCLIDES IN SAMPLES OF ALPS TREATED WATER

Nuclide	IAEA	ASNR	CIRP	KINS	SPIEZ	TEPCO
^{3}H	-2.94	1.12	-0.56	0.11	2.69	-0.40
^{14}C	0.38	1.73	-0.63	-0.48	-	-1.41
^{60}Co	0.67	0.37	-0.49	0.32	-0.57	-0.17
^{90}Sr	-1.50	1.31	0.79	0.47	-0.47	-0.34
^{99}Tc	-0.95	DL	DL	2.08	-2.16	0.95
^{106}Ru	DL	DL	DL	DL	DL	DL
^{125}Sb	0.78	DL	0.17	DL	-0.71	-0.14
^{129}I	DL	DL	DL	Note 1	Note 1	Note 1
^{134}Cs	DL	DL	DL	DL	DL	DL
^{137}Cs	0.29	0.37	0.20	-0.18	-0.60	0.07

DL: As a value less than the detection limit was submitted, no evaluation was performed.

Note 1: Values of -0.30, 0.32 and 0.85 for $\zeta_{KINS,SPIEZ}$, $\zeta_{KINS,TEPCO}$ and $\zeta_{SPIEZ,TEPCO}$, respectively, for ^{129}I.

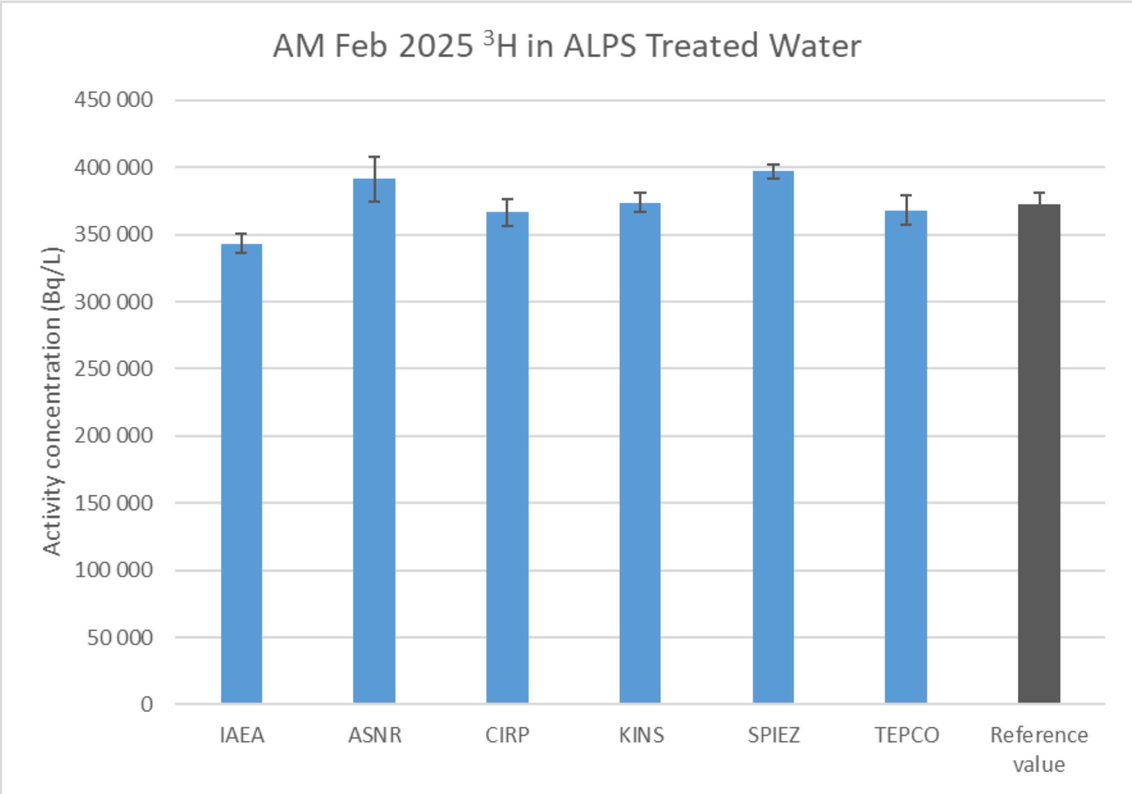

FIG. 1. Activity concentrations of ^{3}H in samples of ALPS treated water.

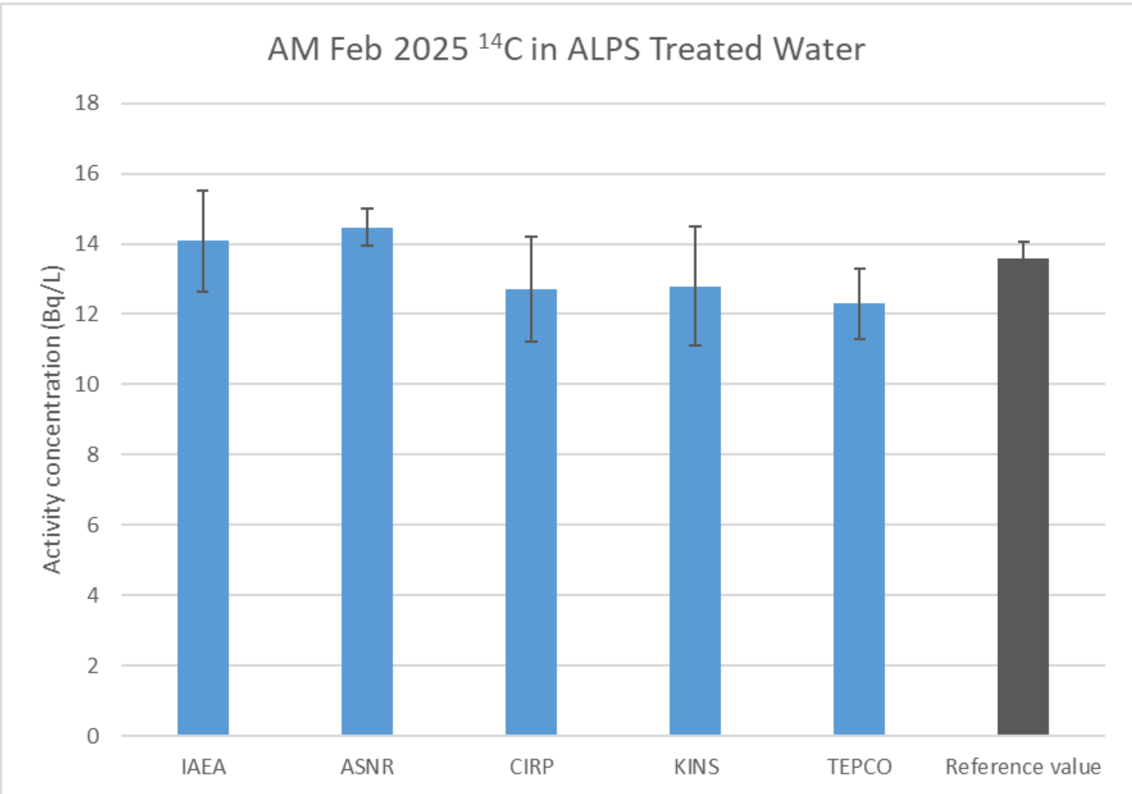

FIG. 2. Activity concentrations of ^{14}C in samples of ALPS treated water.

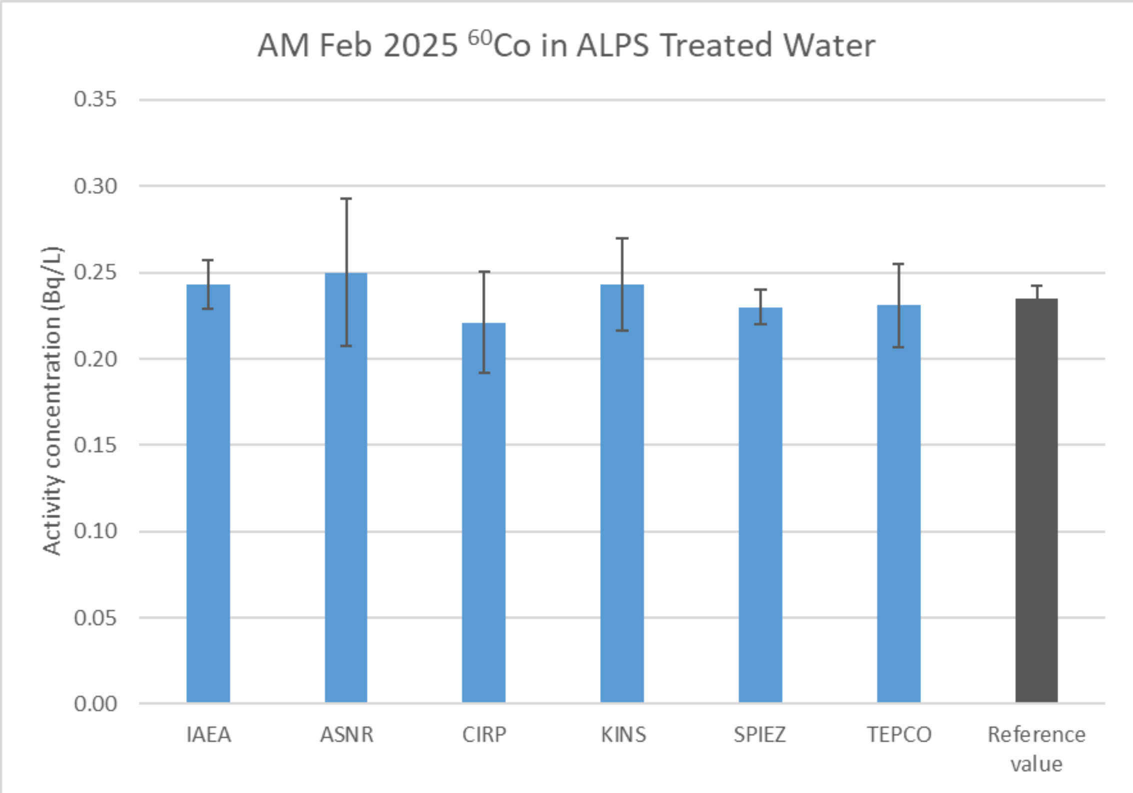

FIG. 3. Activity concentrations of ^{60}Co in samples of ALPS treated water.

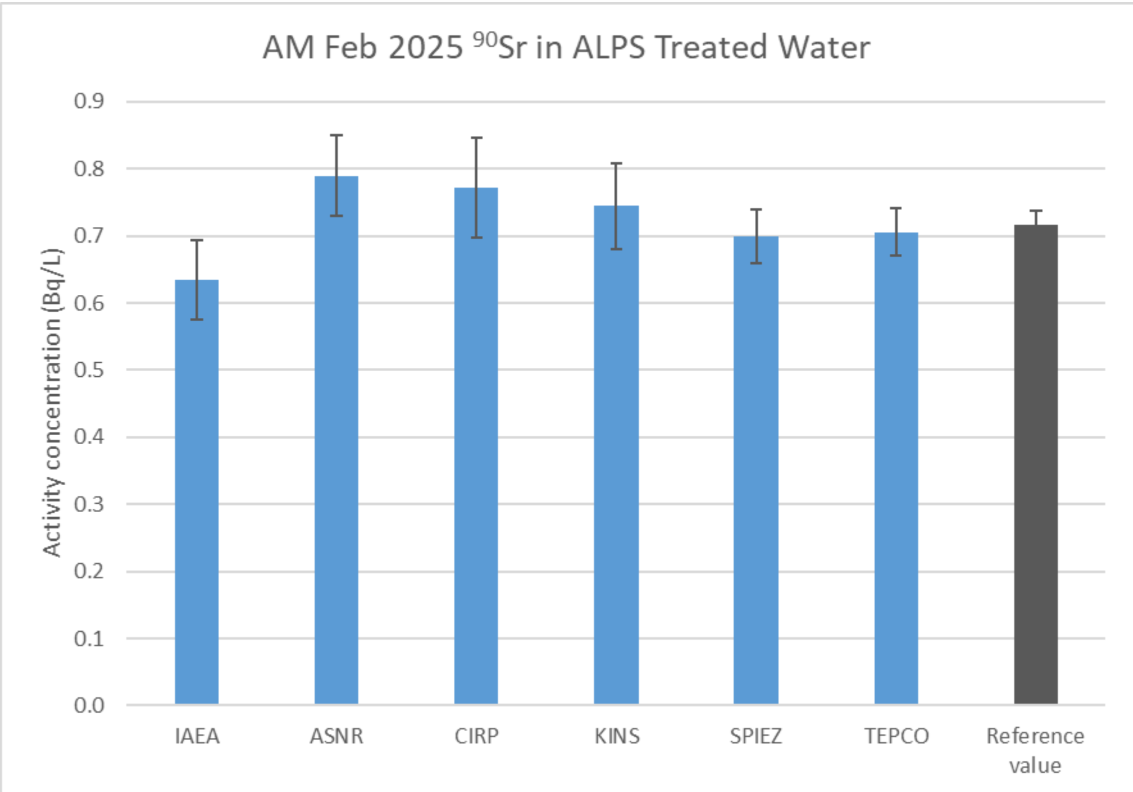

FIG. 4. Activity concentrations of ^{90}Sr in samples of ALPS treated water.

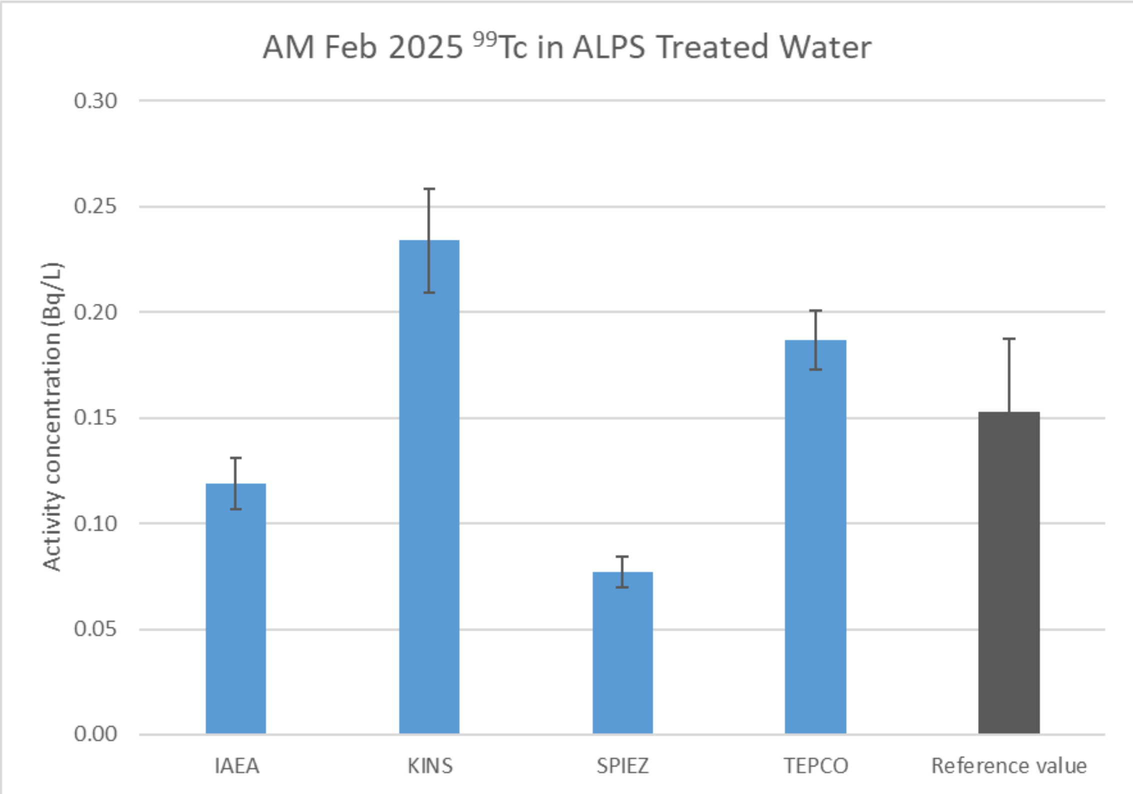

FIG. 5. Activity concentrations of ^{99}Tc in samples of ALPS treated water.

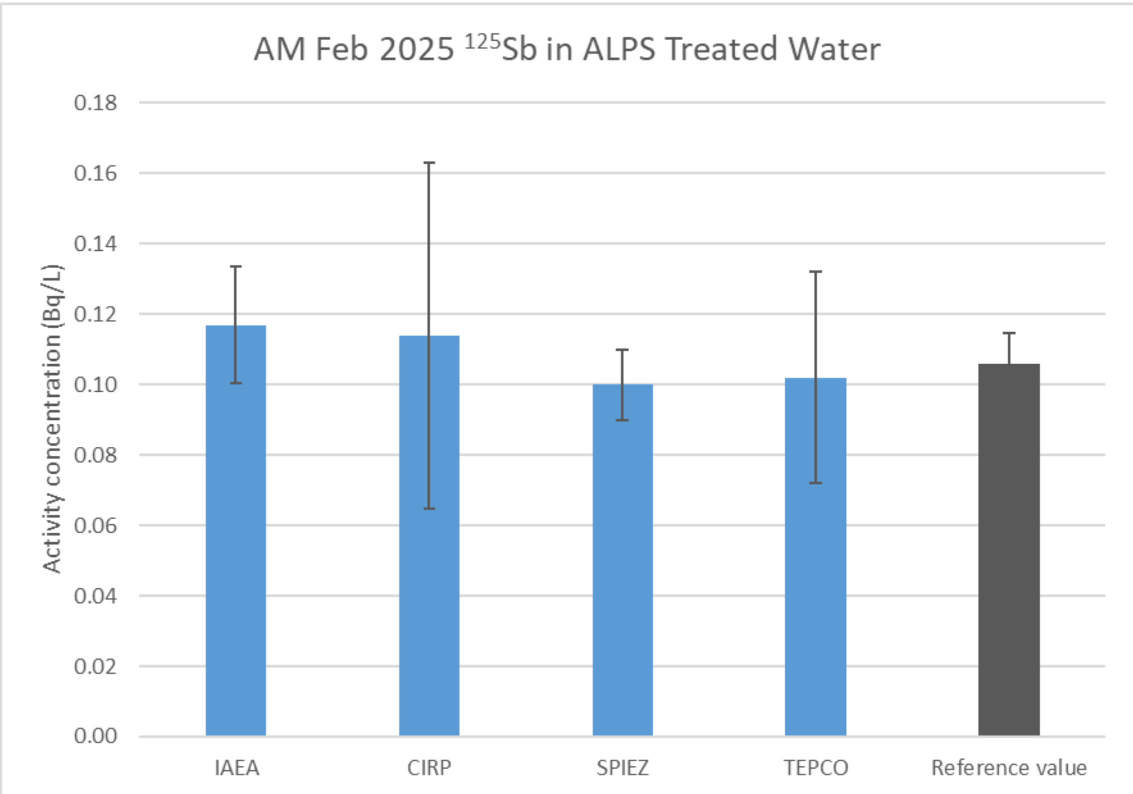

FIG. 6. Activity concentrations of ^{125}Sb in samples of ALPS treated water.

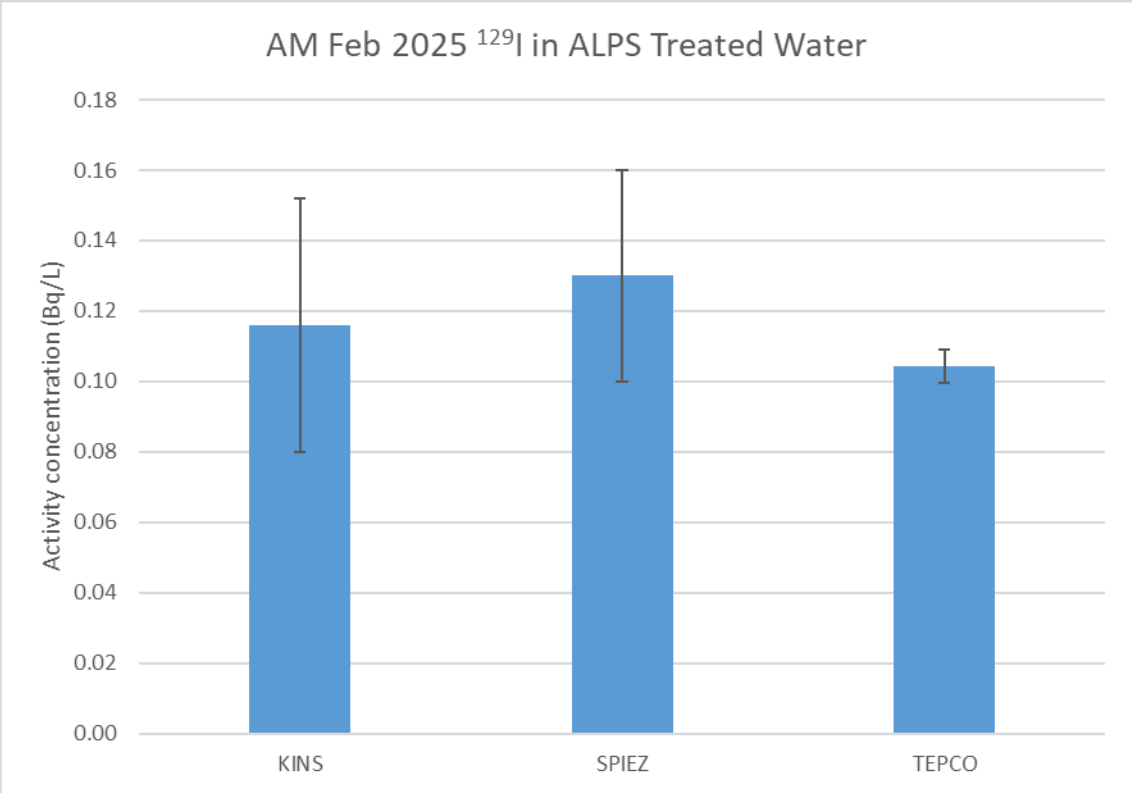

FIG. 7. Activity concentrations of ^{129}I in samples of ALPS treated water.

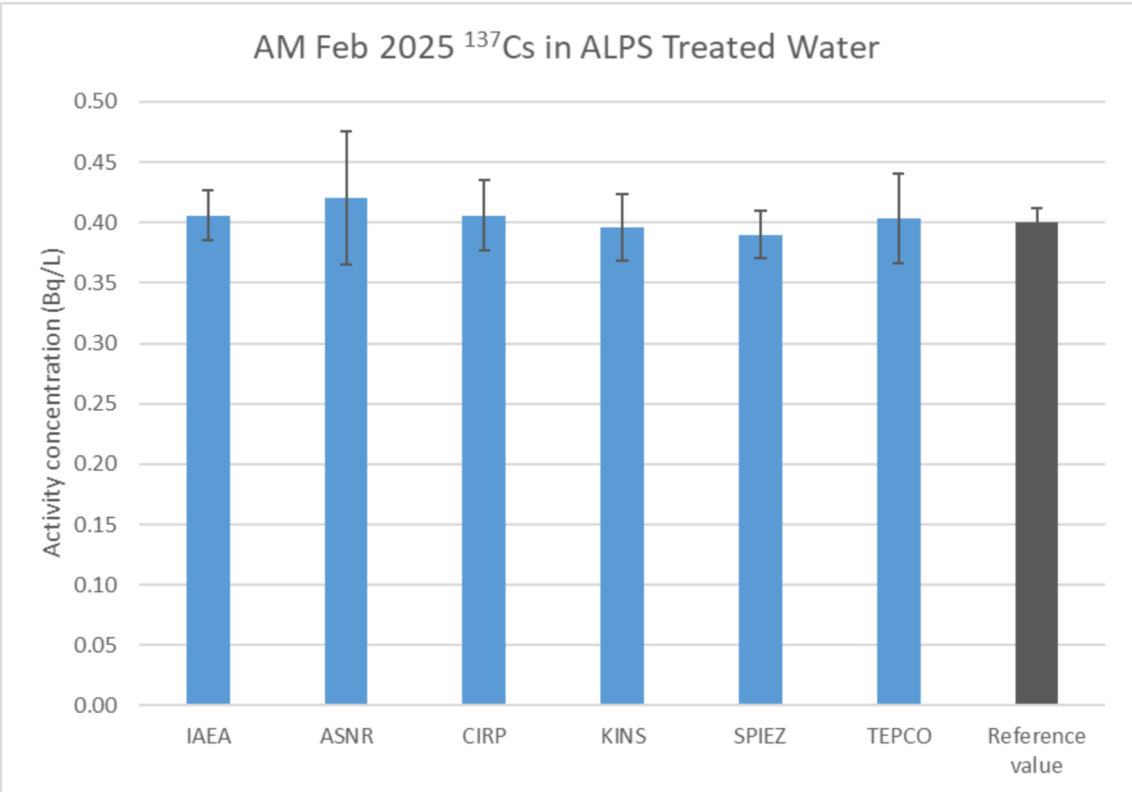

FIG. 8. Activity concentrations of ^{137}Cs in samples of ALPS treated water.

7. CONCLUSION

The results of Additional Measures February 2025: Source Monitoring demonstrate that the measurement results reported by all participating laboratories are in statistical agreement with the corresponding consensus reference values derived from their intercomparison.

These measurement results are consistent with the applicable international safety standards, as well as with the conclusions of the IAEA Comprehensive Report on the Safety Review of the ALPS-Treated Water at the Fukushima Daiichi Nuclear Power Station [5] released in July 2023, which found that the discharges as planned would have a negligible radiological impact on people and the environment.

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