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 June 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 International Atomic Energy Agency'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 June 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 laboratory in Japan, and by member laboratories of the ALMERA Network from Belgium, China, the Republic of Korea, the Russian Federation 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 Fukushima ALPS Laboratory, Japan
CIAE	China Institute of Atomic Energy, China
IPEM	Institute for Problems of Environmental Monitoring, RPA "Typhoon", Russian Federation
KINS	Korea Institute of Nuclear Safety, Republic of Korea
SCK-CEN	Belgian Nuclear Research Centre, Belgium
SPIEZ	Spiez Laboratory (Labor Spiez), Switzerland
TEPCO	Tokyo Electric Power Company Holdings, Inc., Japan

3. SAMPLE COLLECTION AND PRETREATMENT

Samples of ALPS treated water were taken on 17 June 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 14th 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 17 June 2025 12:00 UTC.

5. STATISTICAL EVALUATION OF THE RESULTS

The IAEA compiled and evaluated the results submitted by all participating laboratories. For each radionuclide for which measurement results above the detection limit were reported, 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.

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	CIAE	IPEM	KINS	SCK-CEN	SPIEZ	TEPCO	Reference
^{3}H	399000 ± 1500	365000 ± 5600	384000 ± 24000	390000 ± 7000	366400 ± 10700	410100 ± 7100	378000 ± 14000	385600 ± 6800
^{14}C	47.0 ± 2.4	46.1 ± 4.7	<2.1[1]	49.6 ± 1.4	<3.1[1]	NM	47.3 ± 1.6	48.03 ± 0.98
^{60}Co	0.1454 ± 0.0073	0.14 ± 0.012	0.17 ± 0.03	0.144 ± 0.025	0.122 ± 0.017	0.153 ± 0.005	0.143 ± 0.018	0.1471 ± 0.0042
^{90}Sr	1.160 ± 0.059	1.15 ± 0.06	0.7 ± 0.12	1.125 ± 0.049	1.047 ± 0.068	1.214 ± 0.058	1.076 ± 0.038	1.081 ± 0.059
^{99}Tc	0.079 ± 0.018	<0.20	NM	0.0970 ± 0.0080	0.057 ± 0.009	0.016 ± 0.001	<0.30	0.061 ± 0.018
^{106}Ru	<0.066	<0.24	NM	<1.4	<0.7	<0.071	<0.22	NC
^{125}Sb	0.202 ± 0.019	0.24 ± 0.026	0.27 ± 0.09	<0.46	0.26 ± 0.04	0.195 ± 0.013	0.248 ± 0.035	0.218 ± 0.012
^{129}I	0.209 ± 0.033	<0.51	NM	0.254 ± 0.067	<0.29	0.229 ± 0.038	0.2291 ± 0.0094	0.228 ± 0.010
^{134}Cs	<0.011	<0.019	NM	<0.13	<0.08	<0.01	<0.030	NC
^{137}Cs	0.1581 ± 0.0090	0.17 ± 0.012	0.11 ± 0.02	0.143 ± 0.023	0.14 ± 0.02	0.167 ± 0.011	0.152 ± 0.019	0.1530 ± 0.0073

Notes:

NM: Not measured; no value reported.

NC: Not calculated; as all results reported were below the detection limit, no reference value could be calculated.

[1] The IAEA queried the C-14 detection limits reported by IPEM and SCK-CEN as they were significantly lower than the detected values reported by the other labs. IPEM responded that it needed to check its method. SCK-CEN responded that it incorrectly reported only a detection limit when in fact it had detected a value of 34.3 ± 2.1 Bq/L. As the compiled reported results had already been distributed to all participating laboratories for technical review before this correction was received, SCK-CEN's corrected value could not be evaluated and is not included in this table.

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

Nuclide	IAEA	CIAE	IPEM	KINS	SCK-CEN	SPIEZ	TEPCO
^{3}H	1.96	-2.56	-0.07	0.49	-1.71	2.76	-0.55
^{14}C	-0.49	-0.44	DL	1.33	DL	NM	-0.54
^{60}Co	-0.26	-0.63	0.78	-0.13	-1.53	1.31	-0.24
^{90}Sr	1.03	0.89	**-3.27**	0.61	-0.42	1.75	-0.08
^{99}Tc	0.78	DL	NM	1.91	-0.23	-2.54	DL
^{106}Ru	DL	DL	NM	DL	DL	DL	DL
^{125}Sb	-0.88	0.91	0.59	DL	1.10	-1.72	0.91
^{129}I	-0.63	DL	NM	0.41	DL	0.04	0.17
^{134}Cs	DL	DL	NM	DL	DL	DL	DL
^{137}Cs	0.52	1.41	-2.24	-0.44	-0.68	1.24	-0.05

Notes:

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

NM: Not measured; no value reported.

Values in bold indicate that the reported result disagreed with the reference value at a 99.7% confidence level.

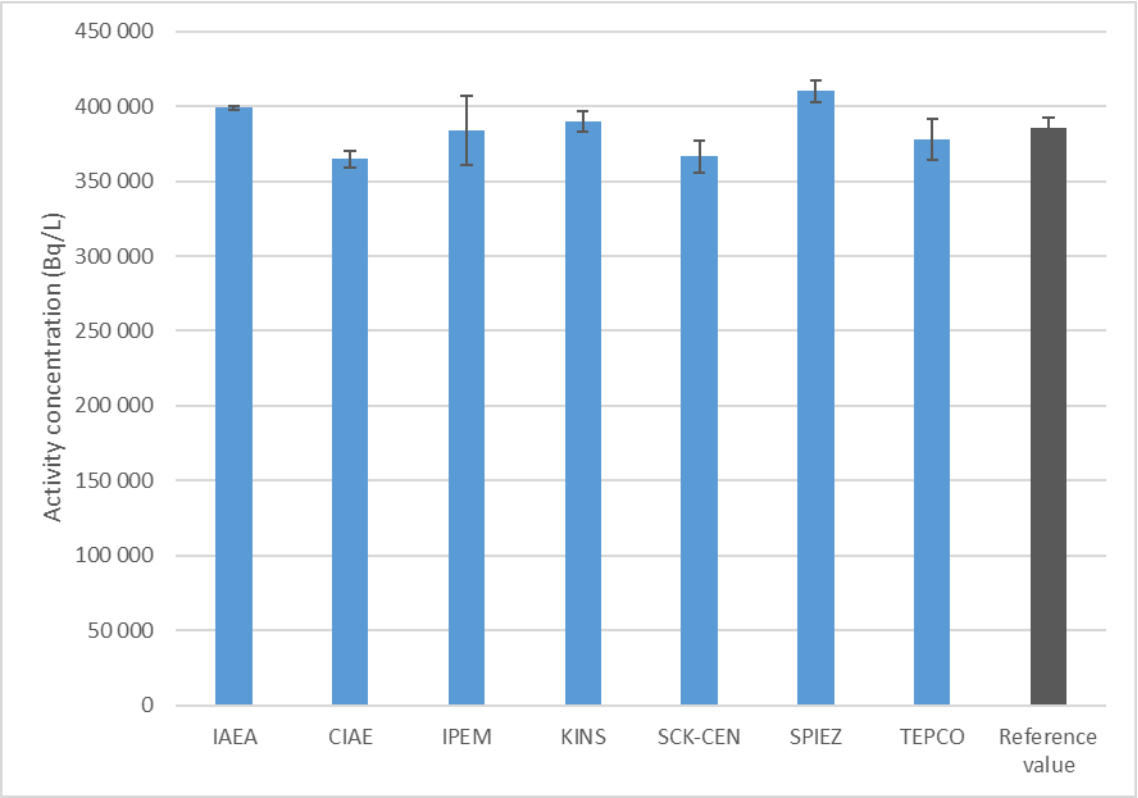


FIG. 1. Activity concentrations of ^{3}H in samples of ALPS treated water.

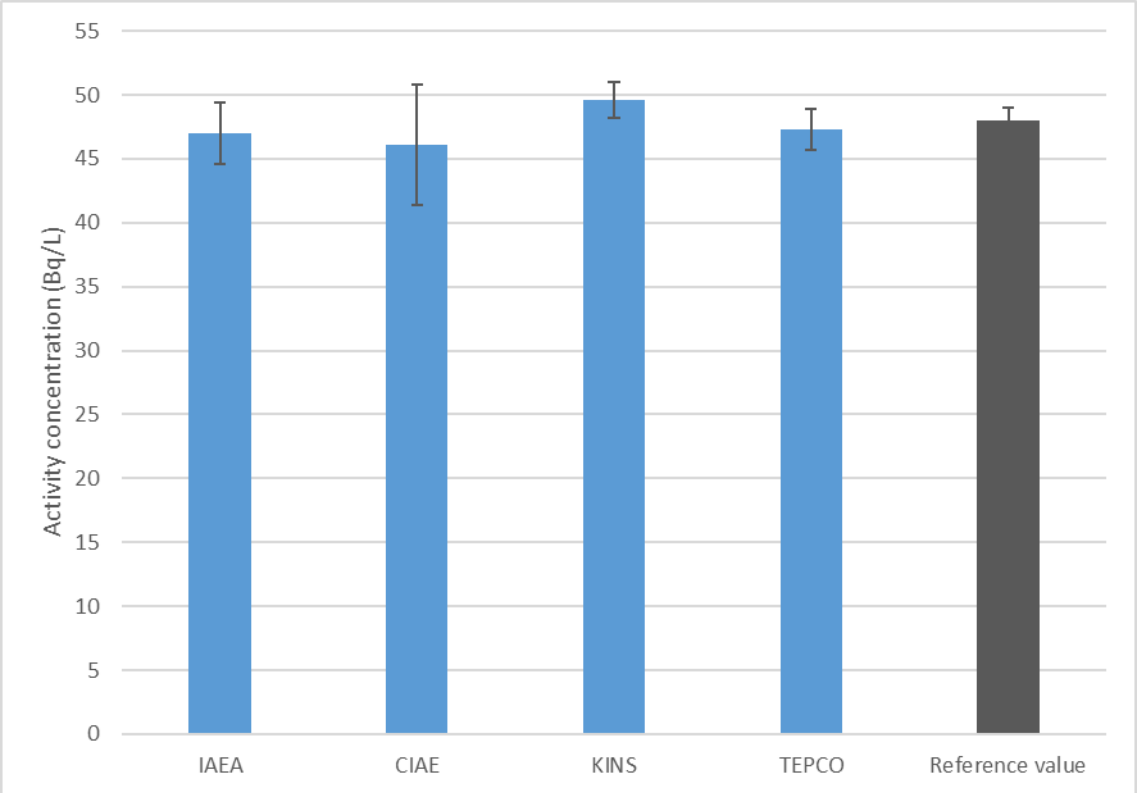


FIG. 2. Activity concentrations of ^{14}C in samples of ALPS treated water.

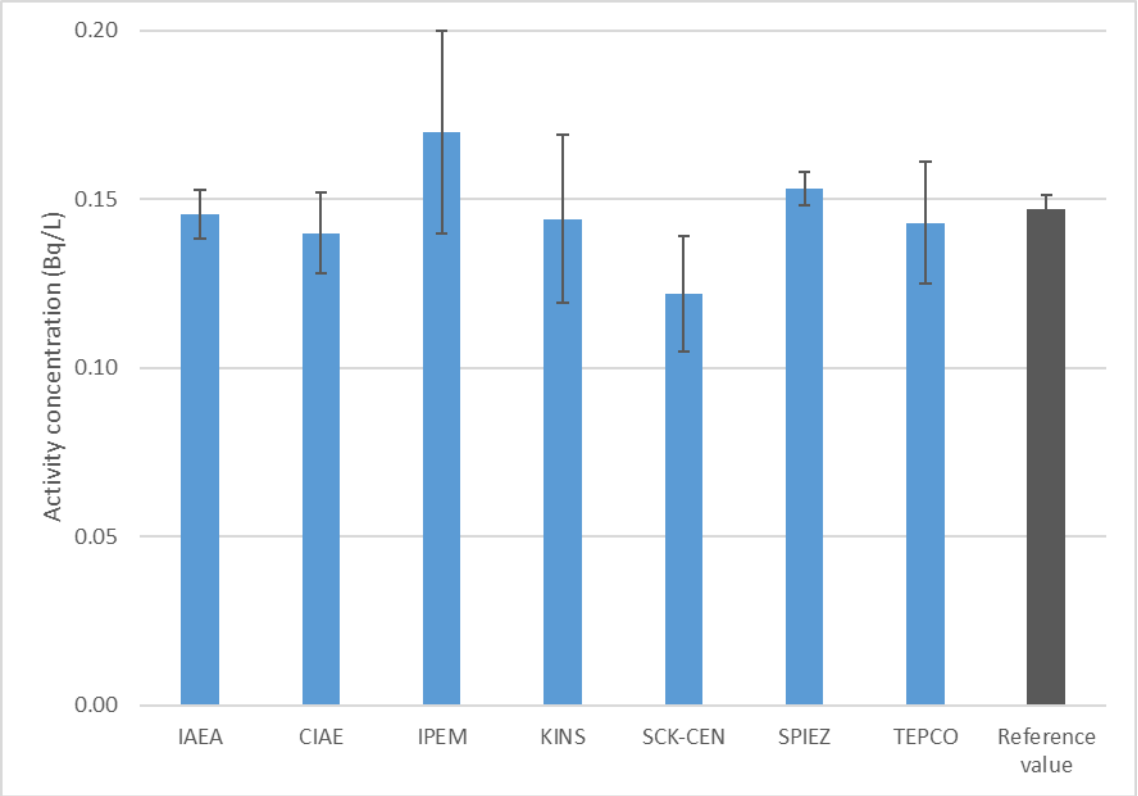


FIG. 3. Activity concentrations of ^{60}Co in samples of ALPS treated water.

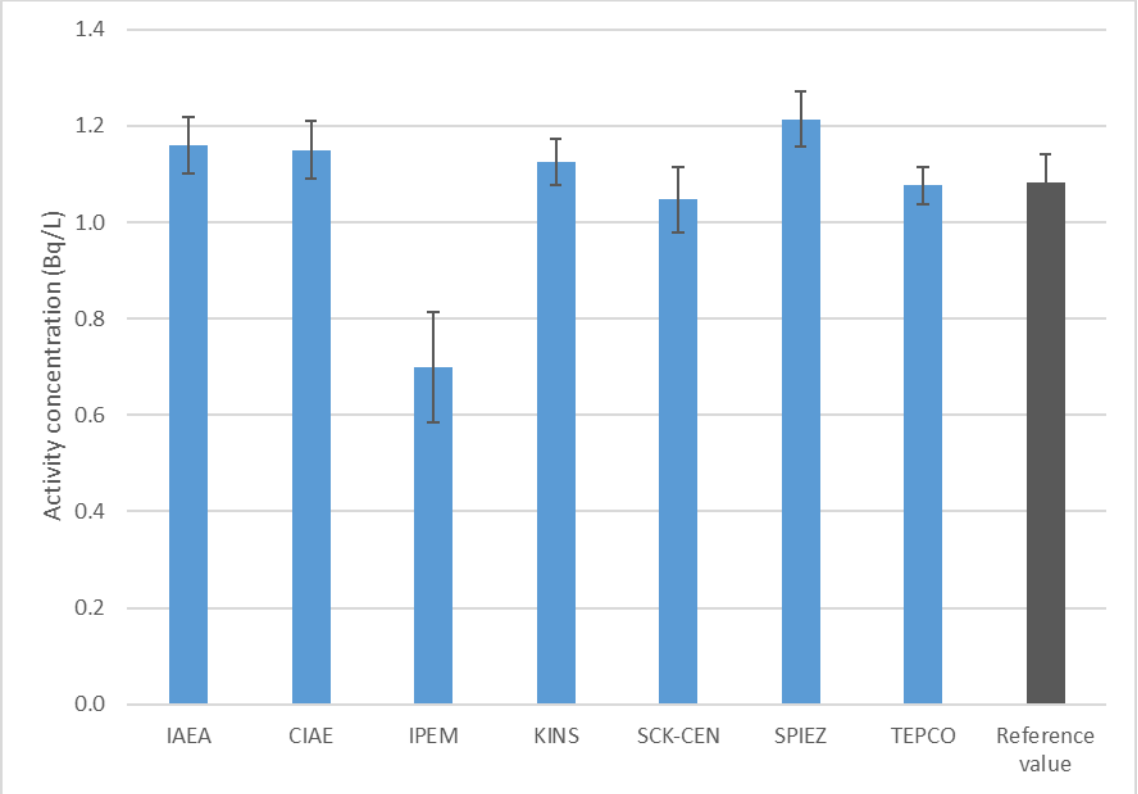


FIG. 4. Activity concentrations of ^{90}Sr in samples of ALPS treated water.

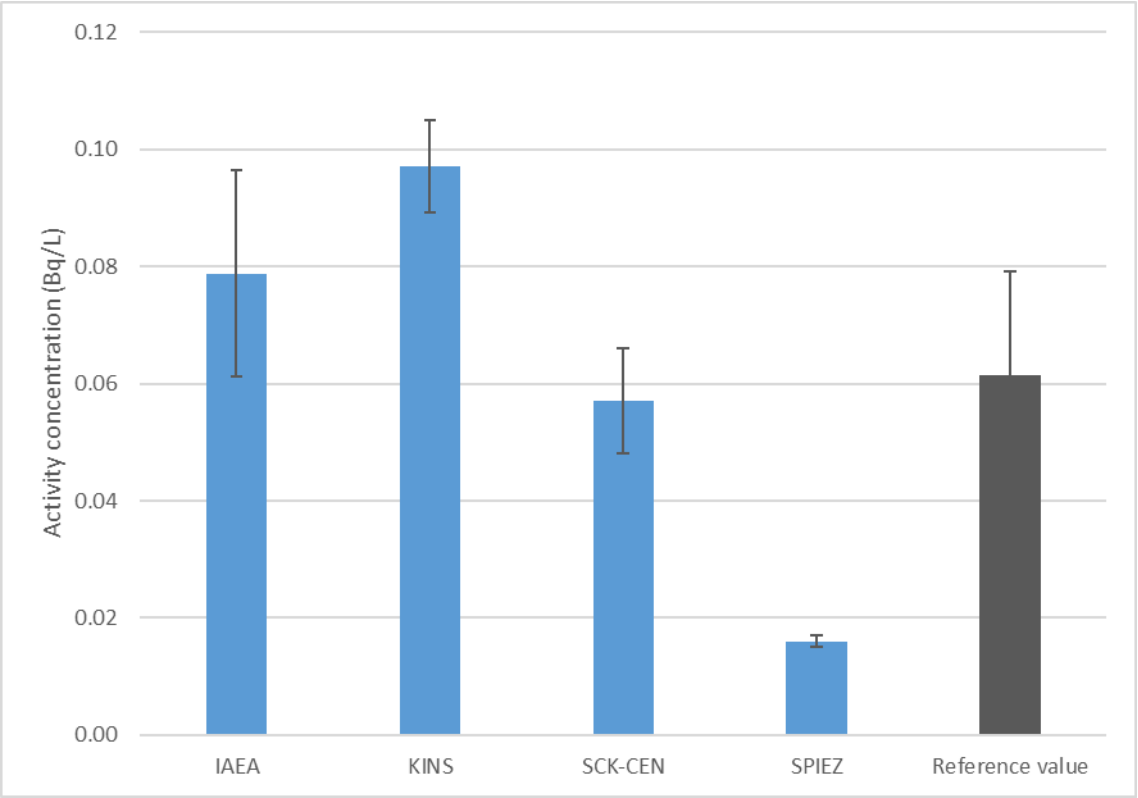


FIG. 5. Activity concentrations of ^{99}Tc in samples of ALPS treated water.

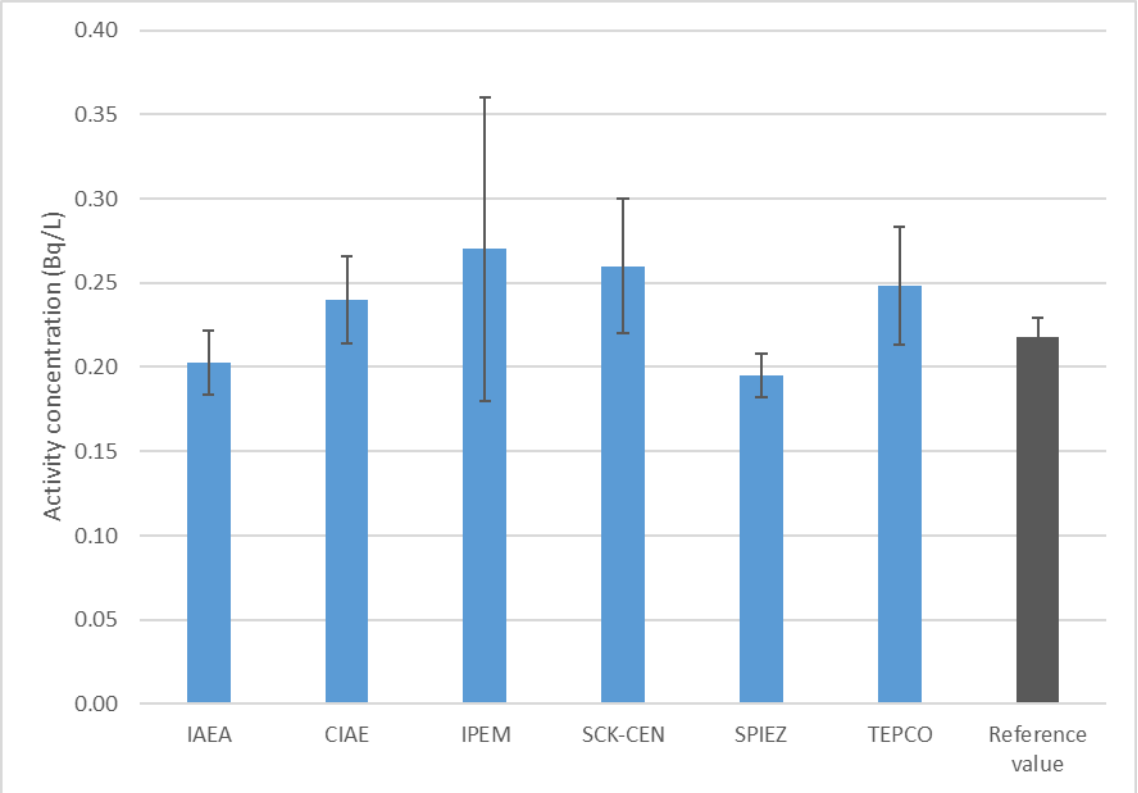


FIG. 6. Activity concentrations of ^{125}Sb in samples of ALPS treated water.

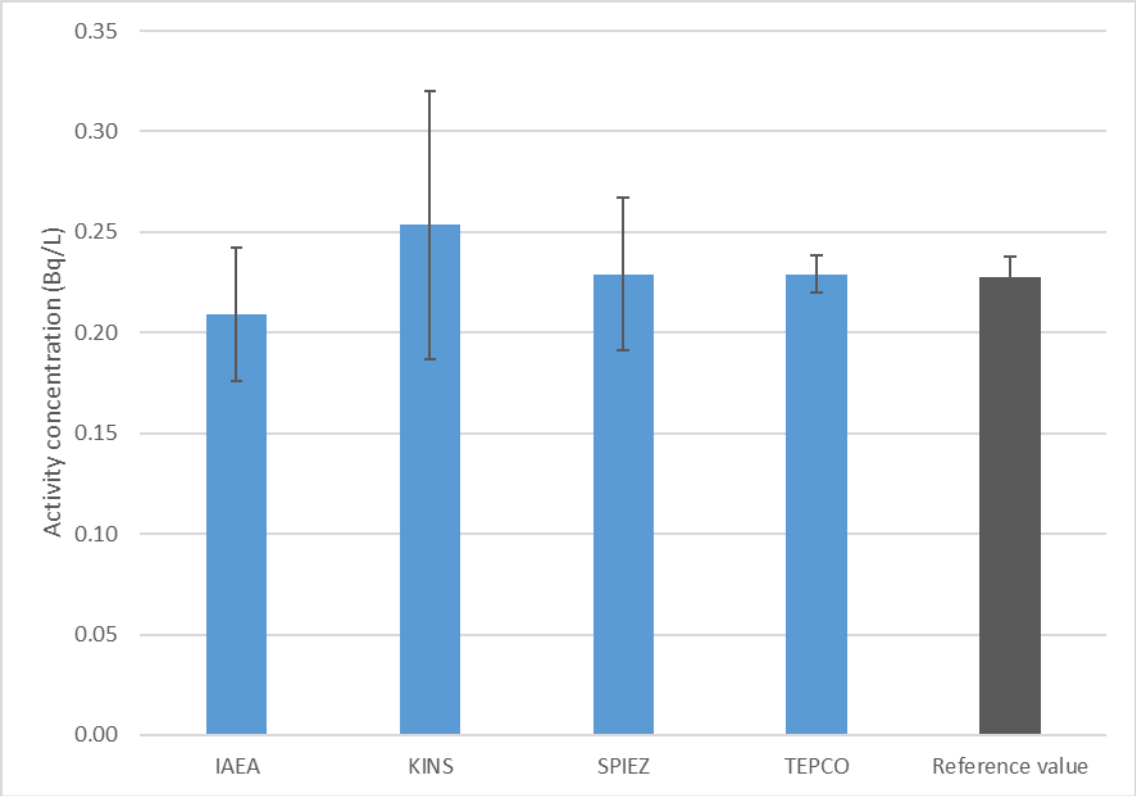


FIG. 7. Activity concentrations of ^{129}I in samples of ALPS treated water.

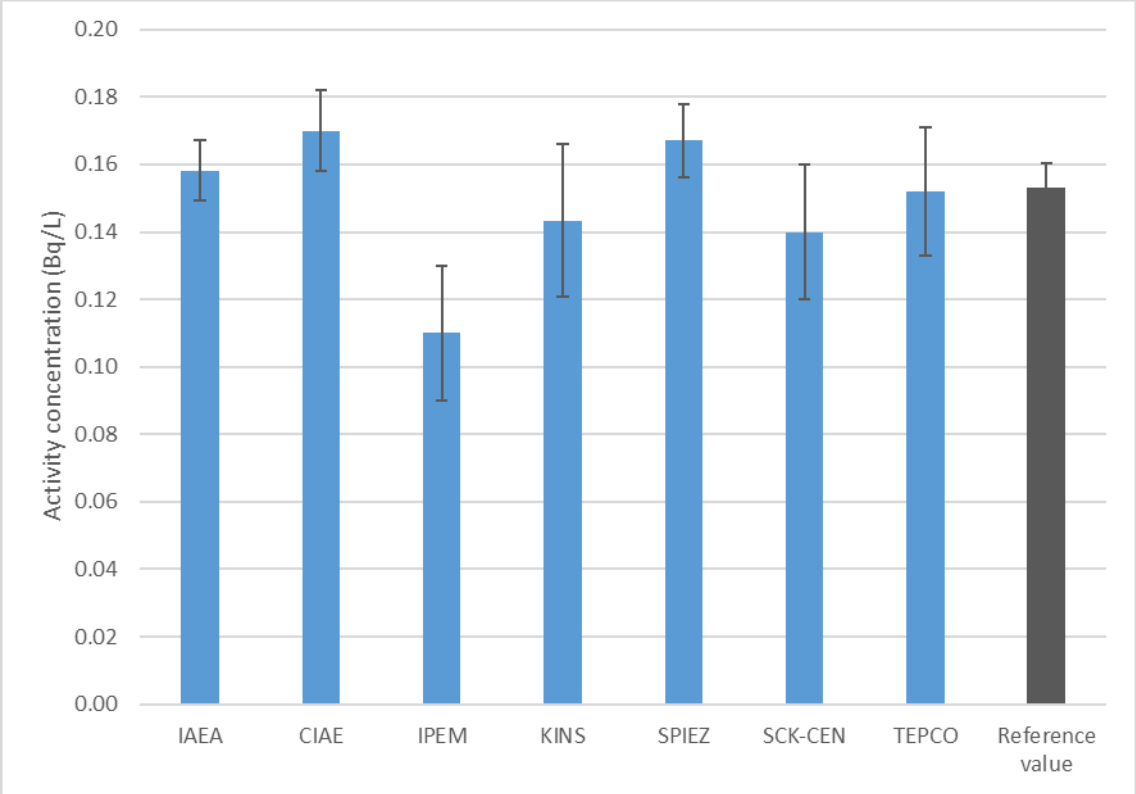


FIG. 8. Activity concentrations of ^{137}Cs in samples of ALPS treated water.

7. CONCLUSION

The results of the Additional Measures June 2025: Source Monitoring demonstrate that the measurement results reported by the majority of participating laboratories are in statistical agreement with the consensus reference value derived from their intercomparison. The single exception was the ^{90}Sr activity concentration reported by IPEM which was reported to be statistically significantly lower than the reference value at a 99.7% confidence level. It is important to note that the magnitude of this deviation is modest and detectable primarily due to the rigorous statistical criteria applied in this analysis. Minor discrepancies of this nature are occasionally observed in laboratory performance evaluations. While further investigation by the reporting laboratory is recommended to identify any potential sources of variance, this deviation does not materially affect confidence in the laboratory's technical competence for performing such measurements in practical applications.

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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