Current Status Survey on Tritium Measurement and Detection Technology

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1. Introduction

In recent, detection and measurement methodologies to handle various phases of the tritium have been emerged as an interest among decommissioning and fusion plant applications. Tritium emits 5.7 keV of average energy and 18.6 keV of maximum energy, the lowest energy among the beta-ray emitter. Due to its low energy, beta particles from tritium cannot traverse far away from their source, rapidly decelerate and lose their kinetic energy. Therefore, the range of tritium among the air has been reported as 6 mm at the largest [1].

In the past, tritium has been treated as low hazardous radioisotope and not sorted as main radioisotopes in a nuclear plant except CANDU reactor, due to its small amount of generation as well as its fastidious measurement. Nevertheless, it has high permeability in the human body, and it can be diffused within a porous substance such as concrete, even metal [2]. As tritium is one of the frequently occurred radioisotopes in the fusion reactor [3], the monitoring and management of radioactive waste management are going to be required for tritium characterization as well as the application for plant decommissioning.

In this paper, we described tritium measurement and detection methods which have been conventionally handled or have been newly developed, also delineated the prospect of the tritium analysis for characterization**.**

2. Conventional analysis of tritium measurements

2.1 Liquid Scintillation Counter

Liquid Scintillation Counter can be applied for analysis of the smear test from the labile contaminant or liquid type of the sample. The scintillation technique, which is the most common analysis method for the tritium measurement [4], requires the mixture of the sample and scintillation cocktail. Solvent and phosphor within the sample mixture convert the radiation energy to the visible light, it can be counted by a photomultiplier tube (PMT). The amount of the tritium can be measured as the tritium decay produce the light flash at the scintillation cocktail. In the case of the solid sample, it should be destructed that can be mixed with the solvent and phosphor material to be investigated. Gas samples also should be gone through complex processes for sampling such as tritium separation, sample dissolution. Moreover, quench correlation interfered by various quenching such as absorption or physical quenching, chemical quenching should be preceded to compare each of the different samples.

2.2 Ionization detectors [5]

An ionization chamber, a gas proportional counter cannot be exploited for the liquid and solid types of the tritium, it can be only applied for the measurement of the gas phase. In the case of the ionization chamber, beta particles occurred from the decay of the tritium ionize the gas within the chamber, the number of the ion varies with the existing gas in the chamber. Then, the amount of the tritium can be deducted by the current obtained by the ionized ions. As measured current proportional to the volume of the chamber, downsizing of the device volume and improving efficiency can be regarded as the main problem. As another ionization counter, the gas proportional counter can be applied to measure tritium by counting pulses which are occurred by passing through the proportional counter chamber, gas mixture consists of counting gas and tritium gas samples dispersed within the chamber. The gas proportional counter has higher sensitivity than the ionization chamber, but it cannot be adopted for the in-line monitor and the in-situ system due to its intricate apparatus.

3. Newly developed methods for tritium analysis

Tritium sampling has been troubled due to its intricate procedure as it can easily interfere with C-14 or other radioisotopes and both radioisotopes can be detected at the same time. Also, at the current progress, there are no technologies or detectors to measure different phases of the tritium, simultaneously, each can be separately investigated. Therefore, efficient and time-saving measurement devices have been required for tritium analysis application, there have been some attempts to surmount the typical challenges in tritium measurement.

3.1. Digital Autoradiography (DA) system [6]

This technique was originally developed and applied for biological and medical studies, but nowadays, it has been rerouted its application to site investigation for decommissioning facilities or radioactive waste measurements, etc. As a non-destructive method, it can be adopted especially for alpha/beta-emitter, contaminations on the surface of the sample can be investigated. It produces the 2D images to present the map of the sample contaminations, close contact of the fabricated scintillation screen with the sample surface can offer the contaminant information.

3.2 TRAMPEL (Tritium Activity Measurements with a PhotomultipliEr in Liquids) [7]

This technique was designed by Priester in 2016, to measure the high activity of the tritiated water with no sampling procedures. It can be conducted by applying a photomultiplier tube with a solution sample, proposed to alternate the typical LSC methods. From 0.0215 MBq/mL to 24 MBq/mL can be measured by this system, proposed for the regular in-line measurement of 10^8 Bq/mL in the plant.

4. Discussion

There have been various tritium measurement devices and techniques adopting different principles and methodologies. The conventional devices exploited conventional methodologies such as ionization, scintillation for the radioisotope measurement, while newly developed devices integrated conventional methodologies with unfamiliar technologies from the new era. Table 1. presents the comparison among the measurement methodologies. For the comparison of the conventional methodologies, corresponding commercial devices were applied.

Table 1. Comparison of the tritium measurement techniques, commercial apparatuses, Tri-carb A 4910 and 1220 Quantulus from Perkin Elmer system (Turku, Finland) as an LSC examples, TAM 100D/DSI from the Canberra (CA, USA) as an ionization chamber example, is applied for the specification comparison of the corresponding measurement methods.

Item	LSC (Tri-carb)	LSC (1220 Quantulus)	Ionization chamber	DA analysis	TRAMPEL
Detection Limit	0.1 Bq/L	0.3 Bq/L [8]	2.5 kBq/m^3	30 Bq/cm^2	0.0215 MBq/mL
Analysis duration	More than 2 days	More than 2 days	-	A day for isotope deposition	In-line measurement
Pre-treatment	O	O	O	×	×
destructive	O	O	O	×	×
In-situ application	×	×	×	O	O

The newly developed measurement method proposed the non-destructive and In-situ applicable systems due to its simplification of the apparatus and elimination of the pretreatment procedures such as sampling and separation. These advantages resulted in the reduction of the analysis duration. However, in conventional measurements, LSC presented the lowest detection limit of 0.1 Bq/L, while other conventional and newly developed devices have not come up to measure the radioactivity level for environmental monitoring. Although the efficient measurement techniques thanks to the in-situ applicable system and time-saving procedures, there are remained for the novel systems to be improved, yet.

4. Conclusion

Conventional analysis methodologies required complicated sampling procedures and labor-intensive tasks or cannot be simplified which is the important factor to be set for the in-line or in-situ systems. Therefore, newly developed methodologies for tritium measurement with the various phases have been highly demanded. According to the demand, new technologies, that are already exploited in the different fields of the studies, have been formatted some fusion technologies for the tritium measurement.

As the prior consideration for the progress in tritium measurements, technologies for in-situ measurement of the tritium contamination in the decommissioning site or the radioactive waste as well as reduction of the sampling procedures should be handled, integration of the conventional measurement principals with the new era technologies from the different field such as medical, artificial intelligence can be the key for the one more of the steps.

REFERENCES

[1] T. Tanabe, Tritium: Fuel of Fusion Reactors, Springer, 2017.
[2] DOE Handbook, TRITIUM HANDLING AND SAFE STORAGE, 2008.
[3] ITER fusion reactor, Retrieve from https://www.iter.org/fr/mach/tritiumbreeding, 2017.
[4] Leo, Techniques for Nuclear and Particle Physics Experiments, Springer Verlag, 1994.
[5] P. Fichet, Review of the different techniques to anlayse tritium, 2018.
[6] P. Fichet, Tritium analysis in building dismantling process using digital autoradiography, J Radioanal Nucl Chem 2012, 291, 869–875, 2010.
[7] K. Priester, Tritium Activity Measurements with a PhotomultipliEr in Liquids-The TRAMPEL experiment, Fusion Engineering and Design, 109-111, 1356-1359, 2016.
[8] Y. Yoon, Comparative Study of Tritium Analysis Method with High-Volume Counting Vial, J Radiation Protection and Research, 45, 3, 2020.