Current Status Survey on Tritium Measurement and Detection Technology

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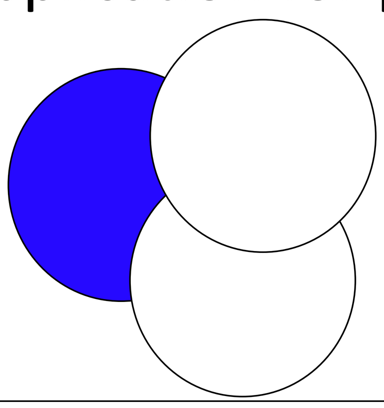
Tritium Measurement

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. 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.



Tritium, ^3H

- Average Energy : 5.7 keV
- (18.6 keV of maximum energy)
- Extrapolated range among the air : 6 mm

Conventional Analysis

- Liquid Scintillation Counter

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. 4π degree measurement enables superb measurement efficiency than other conventional detectors. Quench correlation interfered by various quenching such as absorption or physical quenching, chemical quenching should be preceded to compare each of the different samples.

- Ionization detectors [5]

It can be only applied for the measurement of the gas phase. 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. 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.

Newly Developed Analysis Methods

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.

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 108 Bq/mL in the plant

Comparison

Item	LSC (Tri-carb)	LSC (1220 Quantulus)	Ionization Chamber	DA Analysis	TRAMPEL
Detection on Limit	0.1 Bq/L	0.3 Bq/L	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 measurem ent
Pre-treatment	O	O	O	X	X
Destructive	O	O	O	X	X
In-situ application	X	X	X	O	O

Conclusion & Prospects

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 of in-situ systems. Newly developed devices integrated conventional methodologies with unfamiliar technologies from the new era. It proposed the non-destructive and In-situ applicable systems due to its simplification of apparatus and elimination of the pretreatment procedures such as sampling and separation. 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.

Reference

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

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korean government (MSIP: Ministry of Science, ICT and Future Planning) NRF-2016M2B2B1945082 and the Korea Institute of Energy Technology Evaluation and Planning and the Ministry of Trade, Industry & Energy (MOTIE) of the Republic of Korea (grant no. 20214000000410)