Applied Radiation and Isotopes 104 (2015) 175–180

Contents lists available at ScienceDirect

Applied Radiation and Isotopes

journal homepage: www.elsevier.com/locate/apradiso

A plastic scintillation counter prototype

Etsuko Furuta [a,*], Takao Kawano [b]

[a] Ochanomizu University, 2-1-1 Ohtsuka, Bunkyo-ku, Tokyo 112-8610, Japan
[b] The National Institute for Fusion Science, 322-6 Shimo-ishichou, Toki-city, Gifu 509-5202, Japan

HIGHLIGHTS

- A new device of plastic scintillation counter was developed to measure beta emitters.
- High sensitivity with low detection limit was performed for a tritium compound.
- A detection limit of tritium was 0.01 Bq mL^{-1} for a 10 h measurement.
- A plastic scintillation counter generated no radioactive organic waste fluid.
- A plastic scintillation counter could analyze qualitatively and quantitatively.

ARTICLE INFO

Article history:
Received 11 April 2015
Received in revised form
26 June 2015
Accepted 30 June 2015
Available online 2 July 2015

Keywords:
Plastic scintillator
Prototype device
Tritium
Wasteless
Reusable

ABSTRACT

A new prototype device for beta-ray measurement, a plastic scintillation counter, was assembled as an alternative device to liquid scintillation counters. This device uses plastic scintillation sheets (PS sheets) as a sample applicator without the use of a liquid scintillator. The performance was evaluated using tritium labeled compounds, and good linearity was observed between the activity and net count rate. The calculated detection limit of the device was 0.01 Bq mL^{-1} after 10 h measurement for 2 mL sample.

1. Introduction

The measurement of tritium in the environment is important for our safety in daily life, for developing a fusion reactor without tritium leakage, and for detecting an accidental leakage from nuclear power plants. Generally, tritium, which is the lowest energy pure beta emitter, is measured using a liquid scintillation counter (LSC) because of the high counting efficiency with 4π measurement method. Although a LSC has the demerit of generating a liquid organic waste fluid, it has been used continuously for more than 60 years because of its high counting efficiency, especially for low-energy beta emitters. The high counting efficiency is the greatest merit of the LSC method because the normal environmental tritium concentration is extremely low. No other method had been able to achieve such a high counting efficiency.

To avoid generating a liquid organic waste fluid, there were some attempts to measure low-energy beta emitters using solid scintillators, which were used as substitutions for liquid scintillator for LSC. However, all these attempts using LSC had some issues for measurement; for examples, large standard deviations (SD) of measurement with plastic scintillator sheets (Yang et al., 1991) and the Ready Cap™ (Beckman Catalog, 1991), which was a commercial product, has not been used so long because of its large SD of measurement. PS beads (Tarancon et al., 2005) showed low counting efficiency for tritium, and a PS container (Ogata, 2007) was impossible to detect low energy beta emitters because of using an inner sample vessel. Furthermore, flow-cell type detectors with crushed inorganic scintillators (Hofstetter, 1991) and with CaF_2 (Kawano et al., 2011), which were of same mechanism of a LSC, were produced for environmental radionuclides monitoring; they were useful for only tritiated water, but not to other radionuclides. Additionally, a commercial assay plate; Matrix™ 96 (PerkinElmer) is well used in a life science field without organic waste fluid; however, measurement with these plates instead of LSC measurement has an issue to generate huge amounts of the plastic wastes.

A plastic scintillator (PS), one of a solid scintillator, is a

* Corresponding author.
E-mail address: furuta.etsuko@ocha.ac.jp (E. Furuta).

http://dx.doi.org/10.1016/j.apradiso.2015.06.035

commercial product and has been used to measure beta emitters. PS sheets consist of organic compounds, which include fluorescent material, and we have used PS sheets with the LSC measurement as an alternative material in place of a liquid scintillator (PS sheets method) (Furuta et al., 2009, 2014). The PS sheets method was performed as follows: 1. A PS sheet with a 0.5-mm thickness was cut to dimensions of 45 mm in length by 13 mm in width. 2. A radioactive sample solution was applied to the PS sheet and dried for a few hours in air. 3. The PS sheet was covered with another PS sheet. 4. The pair of PS sheets with dried sample (an assemblage) was placed into a low-potassium glass vial vertically and measured using a LSC. Additionally, a surface treatment with dielectric barrier discharge (DBD) plasma or fluorine gas treatment (F-technique: Takamatsu-Teisan Co. Ltd.) is useful for widening the contact area of the sample when the samples are tritium compounds (Furuta et al., 2014; Yoshihara et al., 2015). The PS sheets method was successful as a measurement method for beta-emitters. It was enough to measure the radioactivity of drain water, which was estimated according to the Japanese regulation: 60 Bq mL^{-1}. Additionally, the PS-sheets could measure beta-emitters without creating radioactive wastes, both of liquid and solid scintillators, because small amounts of liquid scintillator was used only estimation of radioactivity in the measurement and the PS sheets could be used repeatedly (Furuta et al., 2014). However, the detection limit (Bq mL^{-1}) was not very low because the sample amounts applied for the PS sheets were limited to a small-sized PS sheet. Since radioactivity in normal environmental samples is not high without extraction, it is difficult to measure the environmental samples using the PS sheets and a conventional LSC.

The PS sheets method will be a superior method if its detection limit can be decreased. A simple method to achieve this decrease is to make a new special device for PS sheets, which can use larger PS sheets to put on more sample solution, and also to set the assemblage closer to two photomultiplier tube (PMT) detectors.

The objective of this study is to introduce a prototype plastic scintillation counter (PSC), to demonstrate its performance and to clarify the issues involved with the new device development.

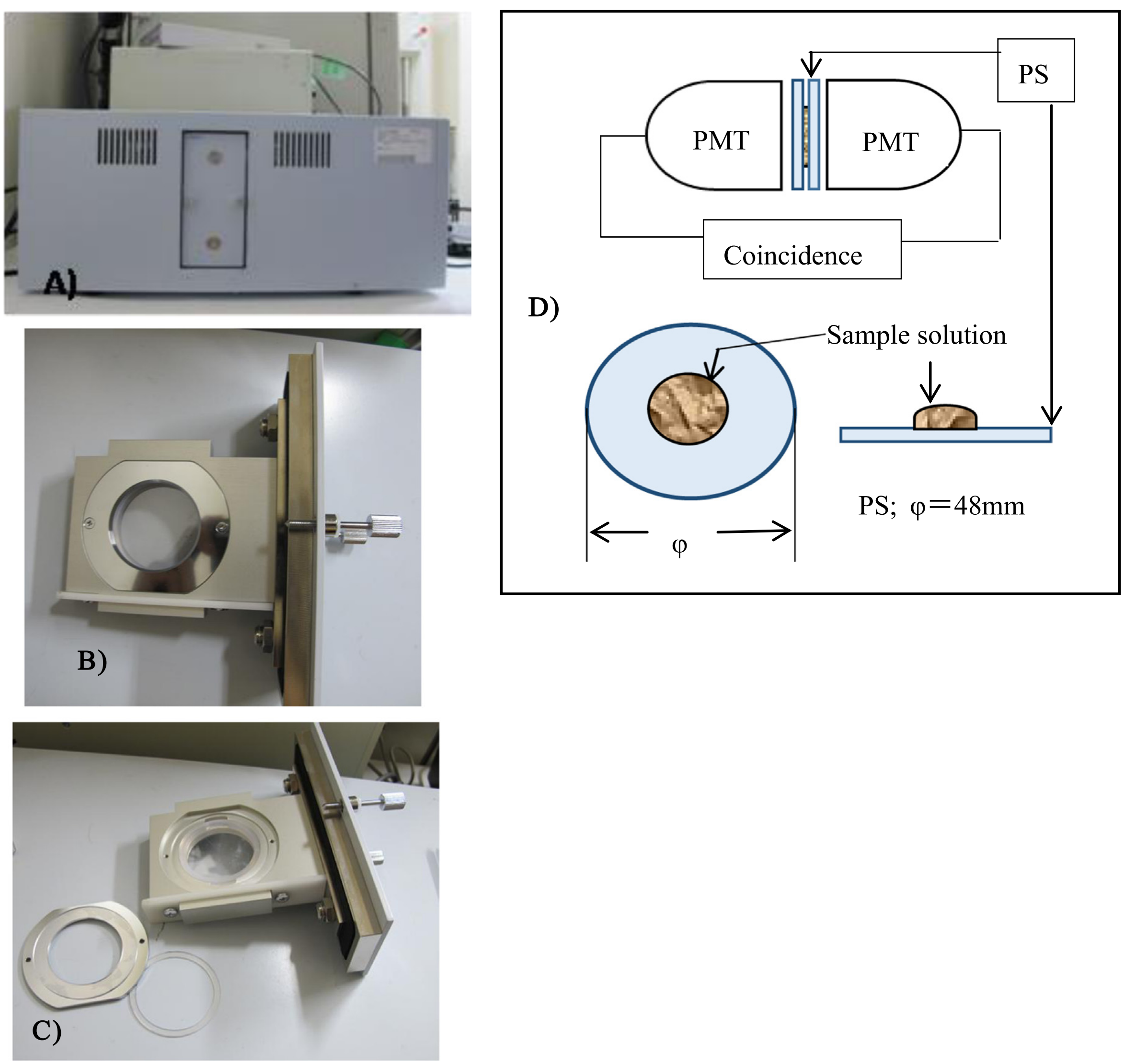

Fig. 1. Photograph of prototype device and a diagram of sample solution preparation. (A) A detector box, containing a pair of photomultiplier tubes (PMT) with a 20.3-mm gap, high-voltage power supply, coincidence-counting module and pre-amplifier: a multi-channel analyzer (MCA) is on the detector box. (B) The equipment to insert a sample into the PS sheets detector. (C) The sample holder in which multiple silicon gum hoops were used. (D) A diagram of a PS-sheet and sample solution preparation. The sample solution was put on a PS sheet with a micro pipet and dried on the sheet, then covered another PS sheet (an assemblage), next the assemblage was placed in the attachment of (B), and inserted among PMTs of (A).