Applied Radiation and Isotopes 109 (2016) 105–108

Contents lists available at ScienceDirect

Applied Radiation and Isotopes

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

Reference drums used in calibration of a plastic scintillation counter in a 4π counting geometry

Chin-Hsien Yeh*, Ming-Chen Yuan

Health Physics Division, Institute of Nuclear Energy Research, 1000 Wenhua Rd. Jiaan Village, Longtan District, Taoyuan City 32546, Taiwan, ROC

HIGHLIGHTS

- Reference drums with radionuclides of 54Mn, 60Co and 137Cs constructed.
- Exchangeable source sets of 9 large-area sources and 9 rod sources.
- Reference drums filled with five materials of different densities.
- Calibration of counters for waste drums of different densities.

ARTICLE INFO

Article history:
Received 13 April 2015
Accepted 19 November 2015
Available online 21 November 2015

Keywords:
Layered sources
Rod sources
Reference drums
Radioactive waste management

ABSTRACT

In this study, two kinds of reference drums were developed. One type was constructed with nine layers of large-area sources filled with different materials having five different densities. The other type of reference drums was constructed with nine rod sources filled with the same materials of different densities. The efficiency calibration of a plastic scintillation counter in 4π counting geometry using these two kinds of drums showed that rod-source drums resulted in higher counting efficiency than layered source drums. The counting rates obtained from rod-source drums were closer to those obtained from a standard drum with water solution than counting rates from drums with layered sources. The results of this study recommend to use reference drums with rod-sources to compensate the drawbacks of standard drums with water solution of not being able to adjust the density of material. The proposed reference drums improve the accuracy of radioactivity analysis for waste drums of different densities.

1. Introduction

According to Anigstein's studies (NUREG, 2004) for decommissioning nuclear power plants, a typical PWR would produce about 37,000 t of metals and 180,000 t of concrete; a BWR would produce 35,000 t of metals and 360,000 t of concrete. Among them, about 70–80% can be released (NCRP, 2002). The solid radioactivity waste intended for clearance is usually placed in 210 L drums and then analyzed for radioactivity with a plastic scintillation counter of 4π counting geometry. When calibrating the plastic scintillation counter, a reference drum with a known radioactivity is expected to be used.

Some authors suggested metal slices to construct reference drums (Yuan et al., 2009, Yeh, Yuan, 2014, Goedrich, 2006) and some authors (Dean, 2007, 2009) used HDPE bottles in reference drums. All of them aim to develop a durable and convenient reference drum to calibrate or test the counting systems which are used to analyze radioactive waste. In this study, we fabricated two types of reference drums with layered sources and rod-shaped sources. By choosing different material density in the reference drums, we established counting efficiency curves for the counting system in dependence of the density of the waste drums. We studied the differences of the counting efficiencies based on these two types of reference drums and verified the results with a standard drum made of radioactive standard solutions.

* Corresponding author.

http://dx.doi.org/10.1016/j.apradiso.2015.11.033
0969-8043/

2. Materials and methods

2.1. Reference drums

In this work, we fabricated 3 sets of layered sources containing one radionuclide per set. Each set contained 9 layers of drop-deposited sources from a radioactive solution traceable to the

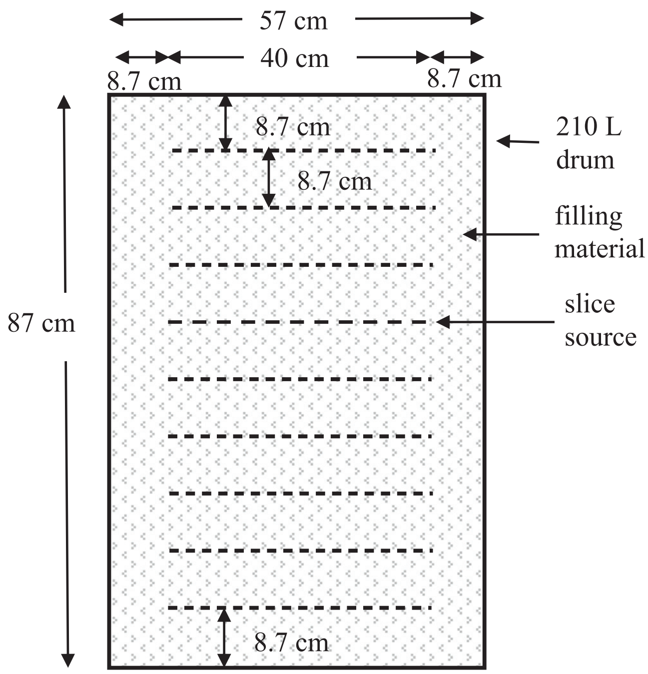

Fig. 1. Sketch of the reference drums with layer sources.

National Radiation Standard Laboratory (NRSL) (Yuan et al., 2009). The layered sources were made of polythene-backed paper and 40 point sources of drop-deposited radioactive solution added with an electronic dispenser on the paper. After drying in air, the paper was covered by 80 µm thick laminating films. The diameter of these large-area sources was 40 cm and the thickness 1 mm. The 3 sets contained ^{137}Cs, ^{54}Mn and ^{60}Co sources, respectively, and their activities were 317 kBq for the ^{137}Cs source set, 260 kBq for the ^{54}Mn source set and 260 kBq for the ^{60}Co source set with an uncertainty of 1.5% (k=2). The total gamma-spectrum of each nuclide was measured in this study. We constructed five 210 L drums filled with cardboard, wood sheet, plastic sheet, cement sheet or glass beads, respectively, with an average density ranging from 0.2 g/cm^3 to 2.4 g/cm^3. Any set of layer sources can be inserted in these drums, evenly interspaced by the filling material of choice, to construct a reference drum with layer sources. A sketch is shown in Fig. 1.

For rod-shaped sources, we also prepared 3 sets. Each set contained 9 rod sources which were made of acrylic tube with 1 cm outer diameter 60 cm length and 2 mm thickness, and filled with a standard solution of one radionuclide in the tubes and sealed. The 3 sets of rod sources also contained ^{137}Cs, ^{54}Mn and ^{60}Co sources, respectively, and their activities were similar to the layered sources. With punched holes in each cardboard, wood sheet, plastic sheet and cement sheet, any set of the rod sources could be inserted into the five drums mentioned before to produce reference drums with rod sources of different nuclides. A sketch of the reference drums with rod sources is shown in Fig. 2.

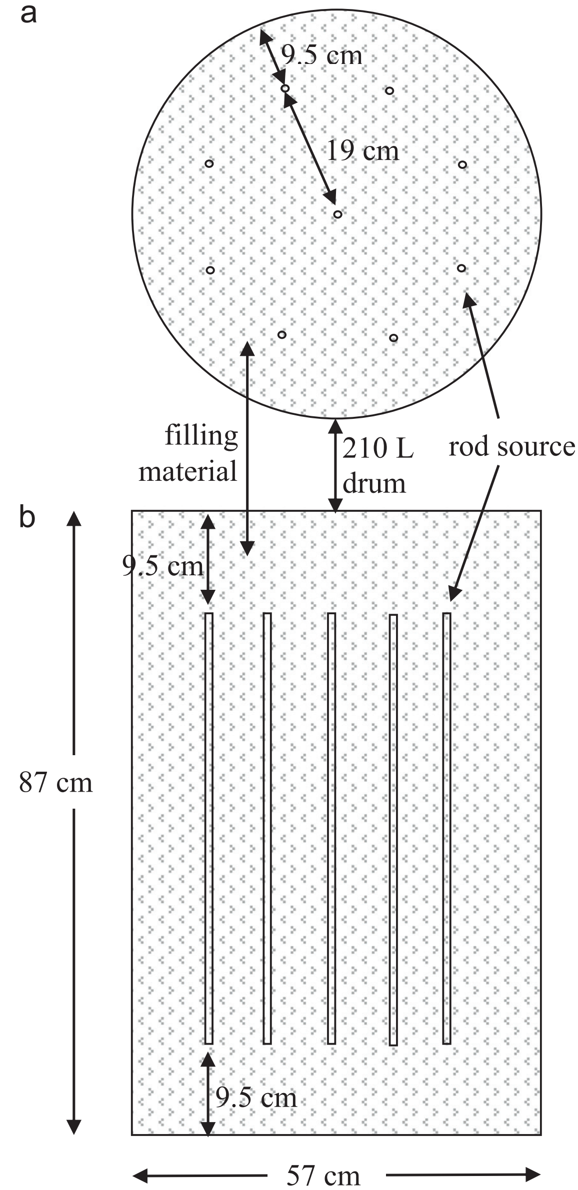

Fig. 2. Structure of the reference drum with rod sources; (a) vertical view, (b) lateral view.

2.2. Counting system and efficiency calibration

A 4π drum counting system of the INER-SWAM2 (Yeh, Yuan, 2007, Yuan et al., 2009) was calibrated by the two types of reference drums. This counting system was composed of ten 40 cm × 30 cm × 10 cm large-area plastic scintillators and sandwiched by a 2 mm thick aluminum liner and a 10 cm thick lead shielding. Each reference drum was measured by the 4π counting system before and after having inserted the layered source set or the rod-shaped source set, and the net counting rate was obtained by calculating the difference of counting rates before and after the insertion of the source sets. In this way, the counting efficiency of the 4π drum counting system for each radionuclide in the five reference drums with different materials could be obtained. The relationship between the net counting rate and the counting efficiency of the nuclides is expressed as

$$N = A_i \times \varepsilon_i$$

where N is net counting rate, A_i is the activity of the ith nuclide and ε_i is the counting efficiency of the ith nuclide. Measurement uncertainties are expressed in this paper at the 95% (k=2) confidence level.