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Quality Assurance of an Analytical Method for Radioactivity Measurement by HPGe Detector

Thesis submitted for the partial fulfillment of Master Degree in Physics (Nuclear Physics)

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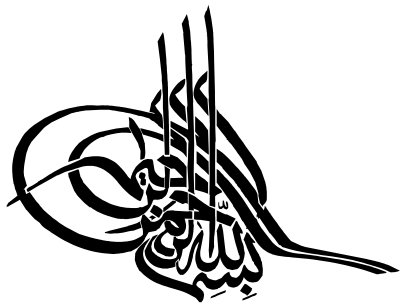

الْحَمْدُ لِلَّهِ الَّذِي هَدَانَا لِهَذَا
وَمَا كُنَّا لِنَهْتَدِي لَوْلا أَنْ هَدَانَا اللَّهُ

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Abstract

In this study, the volume efficiency for a hyper pure germanium detector was determined by a modified mathematical method using the absolute efficiency obtained by using a Ra-226 point source (0.1μCi) at different source - detector distances (0.5, 3.5, 5.5, 7.5 and 9.5 cm).

A relative photopeak efficiency curve using a Ra-226 point source was normalized to an absolute volume efficiency curve using potassium chloride (KCl) solution method. In addition the absolute volume efficiency using KCl results were used to convert the absolute Ra-226 point source efficiency curve (0.1μCi) to an absolute volume efficiency curve. Since in the present study the activity concentrations of soil samples has to be estimated, a factor F_1 was proposed to account for the differences in densities of the KCl solution and the soil samples. The results were in agreement with the results of the mentioned KCl method taking in consideration the correction factor.

To validate the results obtained using the mathematical equation, nineteen soil samples were collected from Ras Shukeir in Egypt; with the same volume (100 ml) as KCl solution volume. The activity concentrations (Bq/kg) of U-238, Th-232 and K-40 were determined at d = 0.5 cm (surface contact). The results were compared with those obtained using the KCl method after correction and were in agreement. The

activity concentrations (Bq/kg) of some of these samples were determined at source - detector distances 3.5, 5.5, 7.5 and 9.5 cm, where only the activities at 0.5 cm were in agreement with the KCl method.

A correction factor F_2 for the volume efficiency using the mathematical equation was proposed to account for density of the medium (air) between the sample and detector, and the results were in agreement after the modification to the mathematical equation at different source to detector distances.

The activities of two of the soil samples were also measured in the Environmental Pollution Lab in the Egyptian Atomic Energy Authority (EAEA) using standard calibration sources of U-238 (RGU-1) and Th-232 (RGTh-1). The results were compared with those obtained using the mathematical method and were in agreement and therefore validates it.

The radiation hazard indices were estimated for the 19 soil samples. The values for all the samples were in the permissible levels.

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Summary

Gamma-ray spectrometry is one of the most widely used procedures to determine the concentrations of natural and artificial radionuclides in environmental samples. The efficiency of HPGe detector is essentially required to determine the radioactivity of unknown nuclides, and it is also important as a fundamental characteristic of a detector. The thesis contains four chapters.

Chapter 1

This chapter contains an introduction about the natural radiation and radioactivity.

The following items are also discussed: man – made sources of radiation like nuclear weapons tests, nuclear accidents, and radiation hazard indices.

Chapter 2

Chapter 2 gives a background about the gamma ray detectors, and discusses the following:

- Interaction of gamma radiation with matter.
- Shielding materials.
- Attenuation of gamma rays in a medium.
- Different types of gamma ray detectors.
- Semiconductor materials.
- The different types of semiconductor detectors.

- Literature review for the determination of volume efficiency.
- Literature review for the determination of activity concentrations for soil samples.
- The aim of the present work.

Chapter 3

This chapter describes the general components of the HPGe spectrometer and explains the present experimental work:

- Determination of volume efficiency for HPGe detector by two methods, the first is a mathematical method using a standard Ra-226 point source. The experimental method is KCl method using two sources of Ra-226.
- Determining of the activity concentrations of U-238, Th-232 and K-40 for 19 soil samples using the two methods to compare and validate the results of the mathematical method.
- Measurement of activity concentrations of two of the standard soil samples in EAEA using U-238 (RGU-1) and Th-232 (RGTh-1) standard sources to validate the mathematical method.

Chapter 4

Chapter 4 consists of the results and discussions of measuring the volume efficiency for the used hyper pure germanium detector by mathematical method and KCl method.

- The absolute efficiency curve obtained by a Ra-226 standard source was converted to an absolute volume efficiency curve