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# Intercomparison NaI(Tl) and HPGe spectrometry to studies of natural radioactivity on geological samples

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In this study, in situ gamma spectra using NaI(Tl) detector have been compared with the laboratory measurements by using HPGe detector on geological samples. The results for measuring naturally occurring terrestrial gamma radiation of $^{40}K$ and the decay series of $^{232}Th$ and, $^{238}U$ respectively of both detectors show a maximum deviation about 5%. The mass activities series from both detectors were checked for coherence using proficiency test procedure from the International Atomic Energy Agency. The reliability and precision pass for final scores for all the analytical determinations of are received “acceptable” for all radionuclides.



## 1. Introduction

Gamma ray spectrometry using NaI(Tl) detector and HPGe detector has been demonstrated as a principal quantitative analysis technique for radioactive measurement at many laboratories in the world. Its major advantages are non-destructive testing, multi-elements analysis, no chemical process for samples, analysis for various types of samples, etc … (Gilmore, 2008). For NaI(Tl) detector is a well-developed and consolidated method for measurements of the naturally occurring terrestrial gamma radiation of $^{40}K$ (1460.8 keV) and the decay series of $^{232}Th$ (at 2614.5 keV of $^{208}Tl$) and $^{238}U$ (at 1764.5 keV of $^{214}Bi$) have broadly been used from mineral exploration to environmental radiation monitoring providing quantitative information. It has a high detection and can work in condition of room temperature. (Chiozzi et al., 2000). The soil samples measure by NaI(Tl) detector using 351.9 keV gamma ray of $^{214}Pb$ compare with gamma ray 1764.5 keV of $^{214}Bi$, it shows that the measurement is good uncertainty and the detection limits for all the samples (Bezuidenhout, 2013). The investigation of the $^{226}Ra$, $^{232}Th$ and $^{40}K$ activities in surface soils of Vietnam shows 42.77 ± 18.15 Bq.kg$^{-1}$ (with a range of 15.02–121.58 Bq.kg$^{-1}$), 59.84 ± 19.81 Bq.kg$^{-1}$ (with a range of 16.07–129.16 Bq.kg$^{-1}$) and 411.93 ± 230.69 Bq.kg$^{-1}$(with a range of 10.47–1085.39 Bq.kg$^{-1}$), respectively (Huy et al., 2012). The background spectrum of a germanium detector is due to a combination of different components such as environmental gamma radiation, radioactivity in the construction material of the detector, radioactive impurities in the shield, cosmic rays and radon gas (Thanh et al., 2010). One developed a method to sharing of count rate at the region 186 keV of the sample containing both $^{226}Ra$ and $^{235}U$ emits gamma transitions of 186.21 keV and 185.71 keV, respectively. (Volgyesi et al., 2014; Varley et al., 2015).

In the work, the activities of radionuclides in the geological sample have been determined using NaI(Tl) detector. In parallel, the results of in situ gamma spectra using NaI(Tl) detector have been compared with the laboratory measurements by using HPGe detectors on geological samples. Performance criteria of proficiency test procedure from IAEA are used to evaluate the measuring activities of the NaI(Tl) results with the HPGe detector as reference value with good agreement follow reliability and precision with final score is assigned “acceptable” for all measurement.

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## 2. Materials and methods

### 2.1. Experimental set-up

The scintillation crystal of NaI(Tl) detector is a cylinder with dimensions of 7.62 cm × 7.62 cm supplied by Canberra, Inc., USA. The NaI(Tl) detector is connected to an Osprey™ (Canberra, 2014) tube which is a high-performance, fully integrated multi-channel analyzer (MCA) tube base that consists of everything needed to support scintillation spectrometry. This compact unit consists of high-voltage power supply (HVPS), preamplifier, and full-featured digital MCA. It can be controlled with only one cable from the Osprey™ to the control and data acquisition system. The HPGe detector supplied by Canberra, Inc., USA, consists of a p-type high-purity germanium (Table 1). The activity of $^{238}$U was calculated based on the activities of $^{226}$Ra (186.2 keV), $^{214}$Pb (241.9 keV, 295.2 keV, and 351.9 keV) and $^{214}$Bi (609.3 keV, 1120.3 keV, 1764.5 keV, and 2204.2 keV), but for the $^{232}$Th, the calculation was based on the activities of $^{212}$Pb (238.6 keV), $^{208}$Tl (583.2 keV, and 2614.5 keV) and $^{228}$Ac (338.3 keV, and 911.1 keV). The activity of $^{40}$K was calculated directly from the gamma line of 1460.8 keV. Acquisitions of gamma rays spectra display and processing are driven by using Genie–2k software that is also used for spectra display and processing of both detectors. The acquisition time is 86400 s for background, reference, and samples respectively. The peak and the overlapping peaks are processed using Colegram software (Lépy, 2004).

### 2.2. Reference sample

The kit standard using three reference sample from the International Atomic Energy Agency (International Atomic Energy Agency – IAEA, 1987), which are RGK-1 (mass activity 14000 ± 400Bq/kg), RGTh-1 (mass activity 3250 ± 90Bq/kg), and RGU-1 (mass activity 4940 ± 30Bq/kg) respectively, have been used to experimentally calibrate the efficiency of the NaI(Tl) detector.

In the order hand, the RGU-1 source was also used to perform the standard curve of efficiency for HPGe detector in energy range from 46.5 keV to 2204.2 keV of $^{210}$Pb (46.5 keV), $^{234}$Th (63.3 keV), $^{226}$Ra, $^{214}$Pb and $^{214}$Bi (in equilibrium with its parent $^{238}$U with mass activity 4940 ± 30Bq/kg) is usually used for the specific assessment of $^{238}$U. We have a sample containing both $^{226}$Ra and $^{235}$U emits gamma transitions of 186.2 keV and 185.7 keV, respectively, we have sharing of count rate at the region 186 keV. We can then use

**Table 1**
Parameters of the HPGe detector.

| | | |
|---|---|---|
| Relative efficiency | | 35% |
| Energy resolution (FWHM) at 1332 keV ($^{60}$Co) | | 2.0 keV |
| Peak-to-Compton ratio ($^{60}$Co) | | 66:1 |
| Geometrical parameters of the detector | Window thickness (mm) | 1.5 |
| | Crystal-window distance(mm) | 5 |
| | Crystal dead layer thickness (outer) (mm) | 0.46 |
| | Crystal dead layer thickness (inner) (μm) | 0.3 |
| | Crystal length (mm) | 50.1 |
| | Crystal diameter (mm) | 62.2 |
| | Crystal hole depth (mm) | 23 |
| | Crystal hole diameter (mm) | 7.5 |
| | Side cap thickness (mm) | 1.5 |
| | Side cap diameter (external) (mm) | 76.2 |

**Table 2**
The information of the standard and samples.

| Sample | Mass (g) | Desity (g cm$^{-3}$) |
|---|---|---|
| RGK-1 | 135 | 1.62 |
| RGU-1 | 130 | 1.55 |
| RGTh-1 | 119 | 1.42 |
| S1 | 140 | 1.68 |
| S2 | 116 | 1.39 |
| S3 | 132 | 1.57 |
| S4 | 136 | 1.63 |
| S5 | 132 | 1.57 |

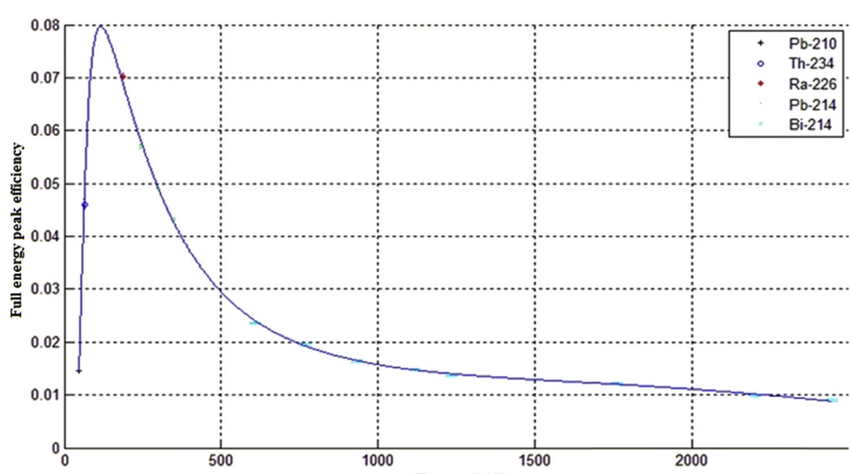


**Fig. 1.** Experimental full energy peak efficiency calibration curve for volume source.