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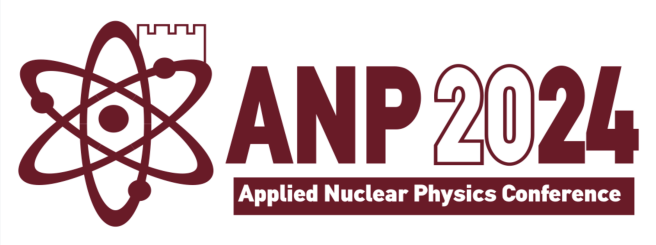

A study of natural radioactivity in thermal springs in Greece using gamma and alpha spectrometry

Ilianna Petropoulou Kynigopoulou, Foivos Gelatsoras, Georgios Siltzovalis, Varvara Lagaki, Ioannis Madesis, Theo J. Mertzimekis

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A study of natural radioactivity in thermal springs in Greece using gamma and alpha spectrometry

I. Petropoulou Kynigopoulou*, F.P. Gelatsoras, G. Siltzovalis, V. Lagaki, I. Madesis, T.J. Mertzimekis

Department of Physics, National and Kapodistrian University of Athens, Zografou Campus, GR-15784, Athens, Greece

Abstract Thermal springs have a geographical distribution that is mostly shaped by major tectonic phenomena, such as volcanic events and extended fault zones. Thermal springs are known to exhibit elevated activities of natural radioisotopes, such as ^{226}Ra and ^{222}Rn. The present work aims to study the natural radioactivity in a few thermal springs in the Hellenic region. Seven water samples were collected from thermal springs in Therma and Nigrita of Serres, Kos Island, and around the perimeter and underwater of the volcanic peninsula of Methana. After preparation, the samples were measured with a calibrated, high-resolution HPGe spectrometer at the National and Kapodistrian University of Athens. Specific activities of natural radioisotopes of the ^{238}U and ^{232}Th series, as well as of ^{40}K were deduced. The same samples were also measured with a factory-calibrated radon spectrometer RAD7 aiming at investigating the correlation of the specific activities obtained by alpha spectroscopy with those deduced by gamma-ray spectroscopy. The results show that such a correlation is clear. In addition, the results extracted with gamma-ray spectroscopy agree well with the values of activities measured in thermal springs, as found in international literature. Further investigation of the correlation between the alpha and gamma spectroscopy in additional water samples, as well as other types of matrices is underway.

Keywords thermal springs, natural radioactivity, ^{222}Rn, alpha spectroscopy, gamma-ray spectroscopy

INTRODUCTION

Thermal springs are one of the important geothermal features on the Earth's surface and occur in areas where geothermal fluid naturally rises to the surface, creating visible hot water flows. As the hydrothermal fluid rises from great depths, it carries dissolved substances and radionuclides from the natural uranium and thorium decay series (^{238}U,^{232}Th,^{235}U), enriching ecosystems with special physicochemical properties [1].

Greece has a diverse geological landscape and is appreciated for its extensive geothermal activity, which includes countless springs, thermal springs, and hydrothermal vents. The multitude of geothermal waters is due to the diverse geology of the country and the geodynamic instability of the region, where tectonic activities, high mountain ranges, and active fault systems play a decisive role [2].

The present study investigates the natural radioactivity of some of the thermal springs existing in the Hellenic region using spectroscopic methods for the detection and quantification of radioisotopes. Specifically, gamma-ray spectroscopy, performed with a High-Purity Germanium (HPGe) detector, and alpha spectroscopy, utilizing a RAD7 radon detector, were employed to measure the concentrations of natural radionuclides. This research aims to improve our understanding of radioisotope distributions in geothermal environments in Greece, but also explore potential correlations between the two types of spectroscopic analysis.

EXPERIMENTAL DETAILS

Seven water samples were collected and prepared for measurement, from thermal springs in Therma and Nigrita of Serres, around the perimeter and underwater areas of the volcanic peninsula of

* Corresponding author: iliannapk@gmail.com

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Methana, and from Kos Island in the Aegean Sea (see map in Fig. 1). Specifically, samples W1 and W4 were collected from Kos, samples P2-0m, P3-0m, and L2B were taken from Methana, while additional samples were collected from Therma Nigritas in Serres prefecture. They were collected in 0.5 L bottles of cylindrical geometry and transported to the Nuclear Physics Laboratory of NKUA for study. All water samples were measured in the two spectroscopy stations (α and γ), see Fig. 2 [3].

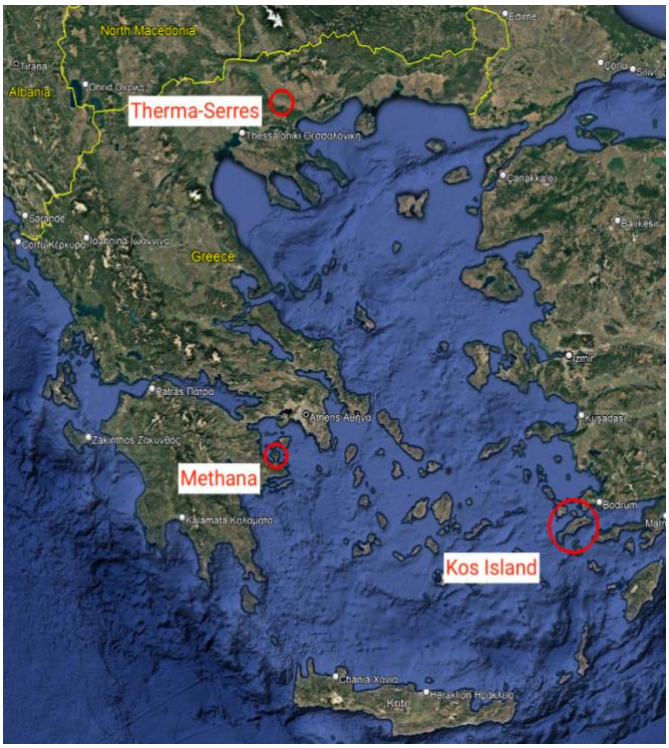

Figure 1 - *A map of Greece showing the sampling locations*

Prior to the measurements, the samples were prepared differently for each detector. For the γ-ray spectroscopy measurements, the water samples were transferred into plastic containers of known weight, so that they could be placed inside the TIGER detector. All containers were sealed and left for at least 15-20 days to reach equilibrium. The duration of the measurements ranged from 20 hours to about 4 days. Spectra analysis was carried out with the SPECTRW software [4].

Additionally, a background spectrum was recorded for 240’000 s, which was subsequently subtracted from the spectra of the water samples (adjusted for measurement time per photopeak).

The energy calibration and the calculation of the absolute efficiency of the detector were also conducted using a standard point ^{152}Eu source. The equation used to fit the data from the point source and deduce the absolute energy efficiency curve of the detector is [5]:

$$y = a\ln(x) + b\frac{\ln(x)}{x} + c\frac{(\ln(x))^2}{x} + d\frac{(\ln(x))^4}{x} + e\frac{(\ln(x))^5}{x}$$

where y is the efficiency, x is the energy in keV and a, b, c, d, and e are free parameters to be determined after the best fit.

For the measurements with the pre-calibrated RAD7 instrument, the same samples were also used after having them transferred from their original storage to glass collection vials. RAD7 uses standardized protocols to determine the radon concentration in 40 ml or 250 ml water samples. The duration of the measurements ranged from 150 min to 450 min following the manufacturer’s instructions. The data analysis, as well as the real-time monitoring of the measurements, were carried out using the CAPTURE software [6].

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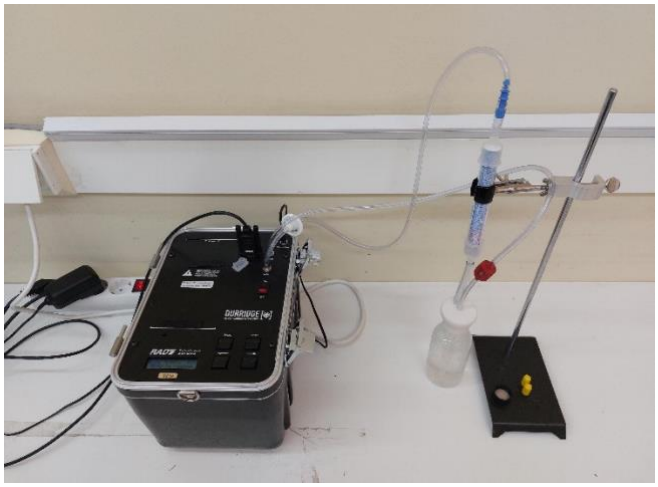

Figure 2. *The RAD7 detector*

RESULTS AND DISCUSSION

After measuring each sample with both detectors, the activities of ^{222}Rn in Bq/m^3 were extracted. Each activity measurement from TIGER was calculated via the photopeak at 352 keV of the daughter nuclei ^{214}Pb, assuming equilibrium.

Figs. 3 and 4 show an example of the spectrum and time series received from the TIGER and RAD7 detectors, respectively, from the W1 sample from Kos Island. Specifically, Fig. 3 zooms in the 352 keV photopeak, while Fig. 4 shows the time series of the ^{222}Rn concentration throughout the full measurement in RAD7.

The comparison of the concentrations is shown in the histogram Figure 5.

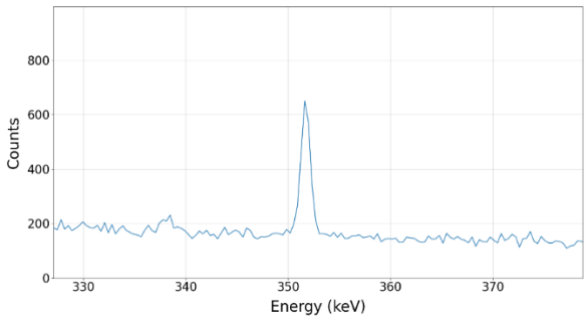

Figure 3. *The 352 keV photopeak for the W1 sample from the spectrum of TIGER*

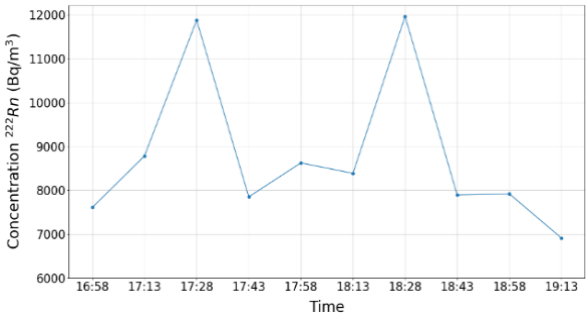

Figure 4. *The time series of ^{222}Rn for the W1 sample from RAD7*

The data reveals both agreements and discrepancies between the methods. For instance, the sample W1 exhibits the highest gamma activity at (13951±1198) Bq/m³, while the corresponding alpha activity is (8800±950) Bq/m³. These results are in relatively good agreement, as the values are within their respective error margins, suggesting that both methods show strong consistency with each other for high radon concentrations. For samples such as W4, P2-0m, P3-0m, L2B, Therma, and Therma-Nigrita, lower levels of radon than W1 were detected. However, the correlation between the methods appears rather inconsistent. The large errors in gamma measurements for these samples suggest challenges in accurately quantifying low to moderate radon concentrations using gamma spectrometry.

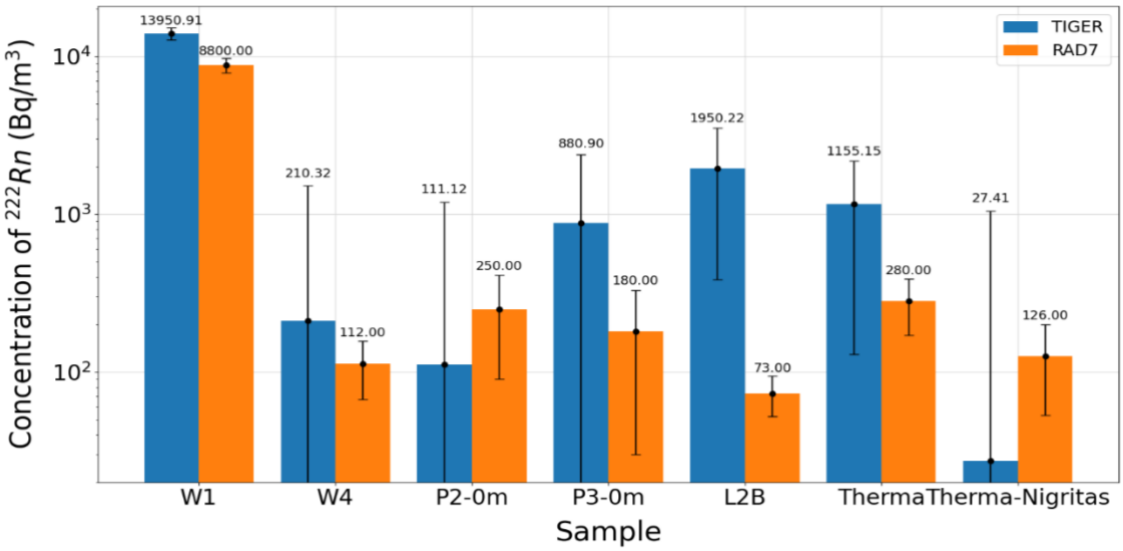

Figure 5. *Comparison of results from γ-ray (blue) and a-spectroscopy (orange)*

CONCLUSIONS AND OUTLOOK

A basic objective of this work was met by comparing the two types of instruments involved in the study. This is the first investigation in the NuSTRAP Lab, where the TIGER and RAD7 spectrometers were cross-checked and the resulting activities agree well and are within the error margins, despite some inconsistencies which can be attributed to the large uncertainties imposed by the γ-ray spectroscopy. In addition, the activity results for the various thermal springs agree with recently published results from similar environments [7,8].

There are two groups of results in terms of radon concentration: one that agrees with the natural background (less than 300 Bq/m^3), and one that has the trend to exceed this limit. In addition, excessive activities are observed in the case of the samples L2B from Methana, and W1 from Kos. Especially in W1 the activity is at least an order of magnitude higher. Because of the high concentration, it is advised that the location be reinspected frequently to monitor potential natural hazards.

The work carried out allows correlating and comparing the results of investigations carried out in the past, in which the HPGe detector was used with the results of investigations using the RAD7 radon detector. For this reason, the investigation may be extended to non-aqueous samples or to a comparison of results between different types of detectors.

Acknowledgments

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